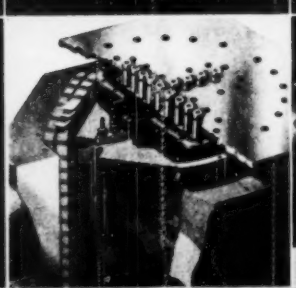
PRODUCT ENGINEERING



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Dec 25, 1961
Vol 32, No 44

PRODUCT

What it is to be a boss 23

You'll need new skills, new viewpoints, if you intend to switch from technical work to a managerial position. Are you sure you're ready? *Roger K Crane*

Charts simplify calculation of airflow in components 26

Pneumatic system calculations depend on manufacturers' component specifications which are not always compatible. Here's how to make them work together in flow computations for air, or for any gas. *Dominic J Lapera*

Shaker armature takes form of a cross 36

Traditional ring-type voice coil is here replaced by stacked cruciform laminations wired to carry the current layer by layer down the stack.

Air lifts freight in free-piston elevator 38

Main valve is controlled by electric signal to brushes riding bus bars on the shaft wall. Descent is simple—just open a bypass valve to let air vent through the cab.

Low-cost latches give high-class results 40

Here are six ways to hold a box cover down that are simple and inexpensive. *L Kasper*

DEPARTMENTS

Advertisers index 86
Design literature 80
Developments to watch 19
Horizons 11
Interesting to note 4

ENGINEERING

To avoid vibration try this new cam profile 42

Based on Fourier analysis, this family of cam shapes is designed to operate below the natural frequency of the follower and thus keep it from bouncing out of contact with the cam. *A S Gutman*

Work forges ahead on full-scale monorails 49

Seattle will have one in operation next April—Japan toward the end of 1962. They both ride on top of the rail—one on air-filled tires, the other with a steel rim laminated to rubber.

Predict engineer shortage of the '60s more serious than ever ... 50

Latest survey indicates engineers well behind scientists in enrollment—well ahead in anticipated industry demand. Shortages accumulating to 140,000 are predicted by 1970.

Saturn success aided by special insulation 54

Plastic and metals combine to reflect and absorb heat from 4500-F rocket flares. Better materials are under study. *R J Ward Jr*

Letters 14
Meetings 16
New components 55
Product designs 36
Reader service cards 87
Your turn 71

COMING NEXT ISSUE

Engineering elastomers

An 18-page special report covering all the latest rubber materials. What are the differences? How do you select the one most suited to your application?

Binary logic

It is basic to all electric, mechanical, fluid-power controls. Here's a teaching machine approach that will make you an eager student in minutes.

6 more low-cost latches

Second half of our review of how to keep a box cover snug against its case simply and inexpensively.

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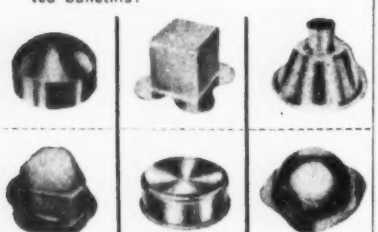

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METAL CRAFTSMEN SINCE 1924

INTERESTING TO NOTE

THE VOICE OF THE WIND—expressed by vibration or pipe (whistles through orifices) effects—has frightened sailors, foresters and ordinary citizens for centuries. Sometimes it has even become an oracle and acquired a cult. Wind instruments, from the pipes of Pan to a pipe organ, are older than sails, but the actual creation of wind for test purposes is little over 60 years old. Capt Charles Renard (1847-1905) of the French Army built the first wind tunnel for his experiments with propellers. He, with A. C. Krebs, built the first practical dirigible on a grant of $40,000 from the French government. He actually made half a dozen circular 5-mile flights with it, returning to a designated spot, in 1884 and 1885, at speeds of 15 mph. What's more, it was the first electrically powered airship—by a 9-hp, 50-rpm, 210-lb electric motor built by Gramme and driving a 23-ft-dia tractor propeller of 26-ft pitch. Renard invented his own chromium-chloride battery to power it, and the power plant proved so heavy that only the crew could be carried in the 4000-lb (total) craft. The balloon was of Chinese silk, over a bamboo trellis, 166 ft long by 27 ft dia (max) containing 66,000 cu ft of gas. The bamboo car was 104 ft long and 4 ft wide.

America's first wind tunnel was built by the Wright Brothers at Dayton just 60 years ago, after they found that most available data on air flow was very faulty. This was to test wing sections for gliders. The tunnel was 8 ft long and 16 in. square, handling the draft from a 2-cyl gas engine driving a propeller. Some 200 wing sections from 3 to 9 in. long were studied in tandem and in tiers for lift and drag. Unfortunately, the models were cut and bent out of sheet metal, so they provided excellent experimental evidence of the importance of a proper aspect ratio, but their constant thickness from front to back obscured from the Wrights all that Wenham and Phillips had known of the necessity for a shaped airfoil. Results tabulated in February, 1902, supplied the Wright brothers with a mine of significant information nonetheless, most of it contradicting what had been known before.

Thus the study of air flow began to catch up with that of hydraulic flow, which had progressed much farther and much earlier, both because of the development of the hydraulic turbine and because water has the virtue of being incompressible. For latest data on air flow through valves, see the article on p 26.

A mathematician's mathematician

The golden age of mathematics. That's what they called it, though it might be more accurate to call it the golden age of mathematicians.

France. Eighteenth century. The physics of Newton (1642-1727) and the mathematics of Leibnitz (1646-1716) were percolating through Europe like bubbles of champagne, stimulating the minds of scientists and philosophers everywhere.

France, eighteenth century, and the names of the greats read like a hall of fame: d'Alembert (1707-1783), Clairaut (1713-1765), Lagrange (1736-1813), Laplace (1749-1827), Legendre (1752-1833), and finally, Fourier (1768-1830). Preceding Napoleon I into the world by a year, Jean Baptiste Joseph Fourier was born the son of a tailor and soon to be orphaned. Like Napoleon he went to military school and would have joined the army except for the "lowness of his birth and his poverty". So, while Napoleon became an artillery officer, Fourier turned to mathematics. He taught math at the school in which he first studied and also lectured on rhetoric, philosophy and history. At 27 he was sent to lecture at Ecole Normale in Paris, and soon afterwards to the Ecole Polytechnique where he sat in the Chair of Analysis.

Somewhere in the following three years the two—Napoleon and Fourier—must have met because the next major entry in Fourier's biography

continued, page 6

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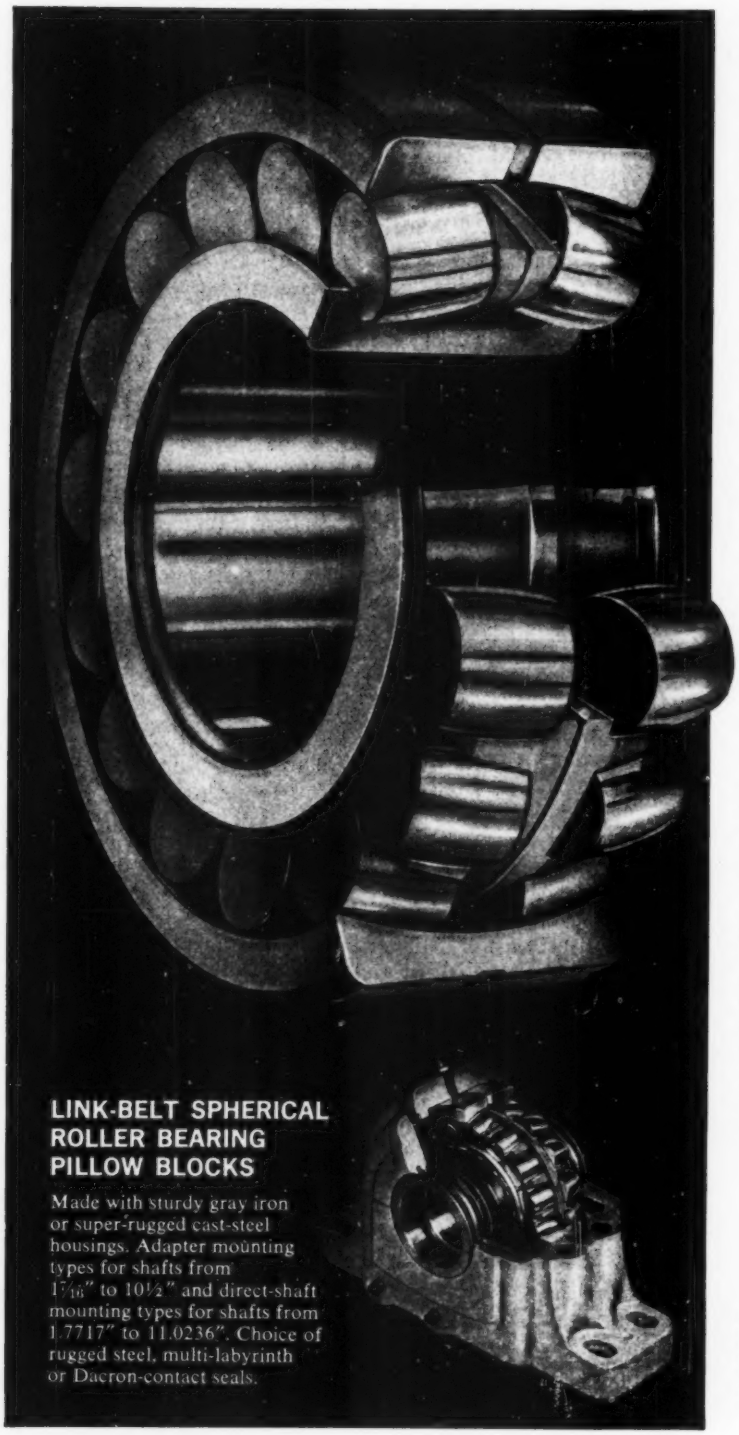

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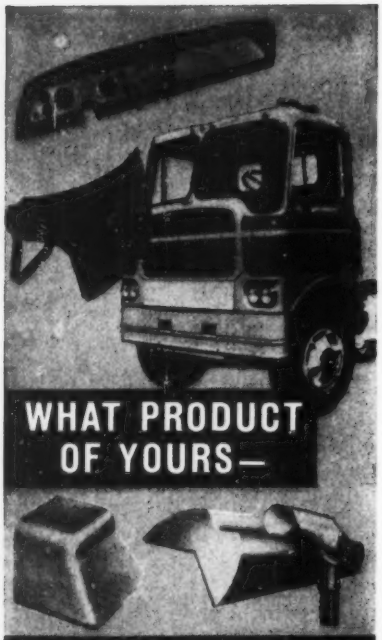

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INTERESTING TO NOTE *continued*

has him on the way to Egypt with Napoleon (as one of his *savants*). At this point Fourier was 30 years old (Napoleon was 29). He was called upon to execute several important political assignments in addition to his scientific "advisories" and he must have done well because soon after he was made governor of all of lower Egypt.

From here on his career was all glory. He continued as friend of Napoleon until Elba, at which point he switched to royalist and this caused him some minor discomfort when Napoleon returned. But after Waterloo and the exile at St Helena, Fourier returned to favor. He moved to Paris, where, elected to the Academie of Sciences in 1816, he began to reap the respect his earlier mathematical exploits had earned him. The crowning glory: In 1827 he succeeded Laplace as president of the council of the Ecole Polytechnique.

And so mathematicians do make good politicians—and sometimes quite foresighted ones. Though that's not what we remember them for. What put Fourier into the mathematical hall of fame? Two great ideas: One, the theory of heat transfer in solid bodies. Conductive heat flow is a direct function of temperature difference and area and time, and inversely proportional to the thickness of the body through which it flows. You have to throw in a constant which sets the units right and takes into account differences in the conductivities of various materials, but the essential formula is exactly what we use today in designing air conditioning for a house, heating the water in a boiler and calculating the temperature of our satellites in outer space. As a matter of fact, today the flow of heat in three-dimensional bodies presents some of the toughest mathematics our computers face—all based on Fourier's simple, fudge-factored little equation.

And the Fourier series (Fourier's folly, we called it in school). We had better not forget that. This is the series of sine and cosine terms with each succeeding term made up of a higher multiple of the original angle. It's one of those general formulas which, when looked at in a certain way, accumulate half a handbook's contents as just a bunch of "special cases". They're leaning heavily on Fourier in servo-theory, but it turns out that even simple cam shapes can be improved when examined in the light of Fourier's folly. See what our author does with it on page 42.

Masterpiece

It is interesting to note that, in contrast to such words as colossal, stupendous and magnificent, which have been so deflated by Hollywood, the word masterpiece has gone the other way. Originally, it meant the piece a journeyman made for the wardens of his guild to prove his right to be a master of his craft. This is the sense in which we use the term in our annual Master Design Awards, the third series of which has just been announced (*PE—Nov* 27 '61, *p* 28). Entries must be in earlier this year—by Jan 15—and awards will be announced in our April 16 '62, issue. The program is unique in that the individuals concerned with the design are recognized rather than the company. If you want an entry blank, drop us a line promptly—or use the reader service card.

Second thought in connection with the word "master" is in the management sense, where there are no criteria except success. So much engineering is going into modern products that engineers are in increased demand for management—for masters not of product design but of men. Beyond that, our social system puts the management man above the technical man on the social totem pole, so the pressure is on engineers to prove their competence by entering management. But being the boss is not only status and income; there's another side. To find out more about it, see "To be a boss" p 23. What's more, demand for engineers is still on the way up, but engineering enrollments are still on the way down. For the latest from National Science Foundation on the subject of the supply and the need for engineers, see p 50.

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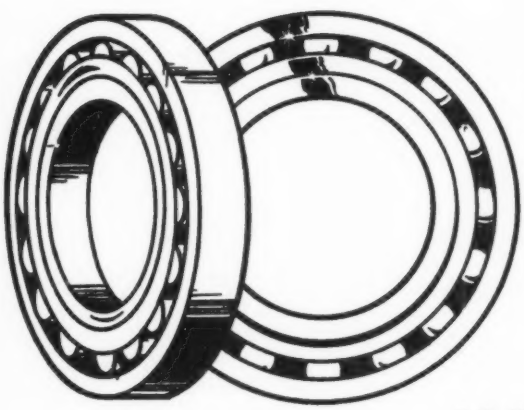

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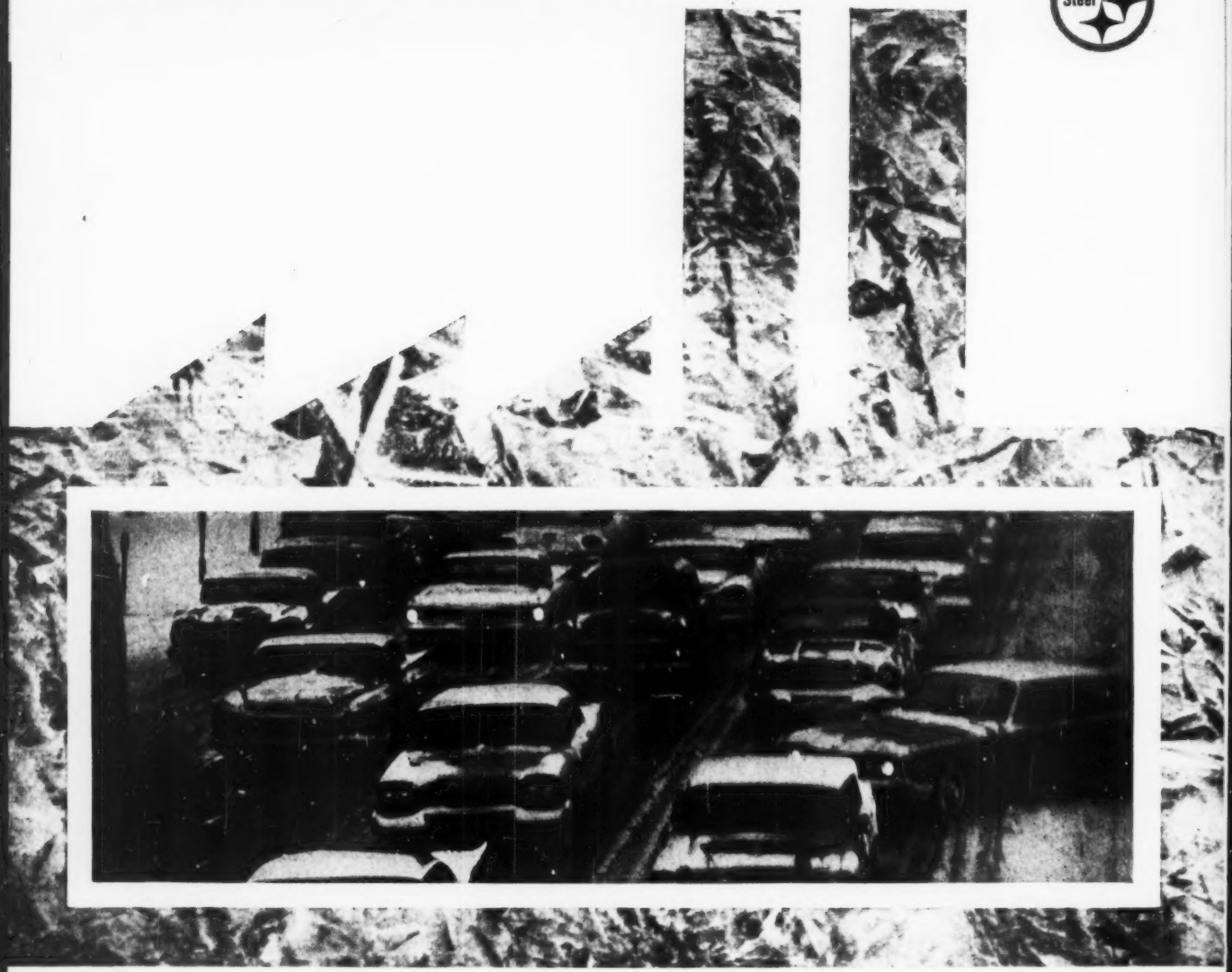

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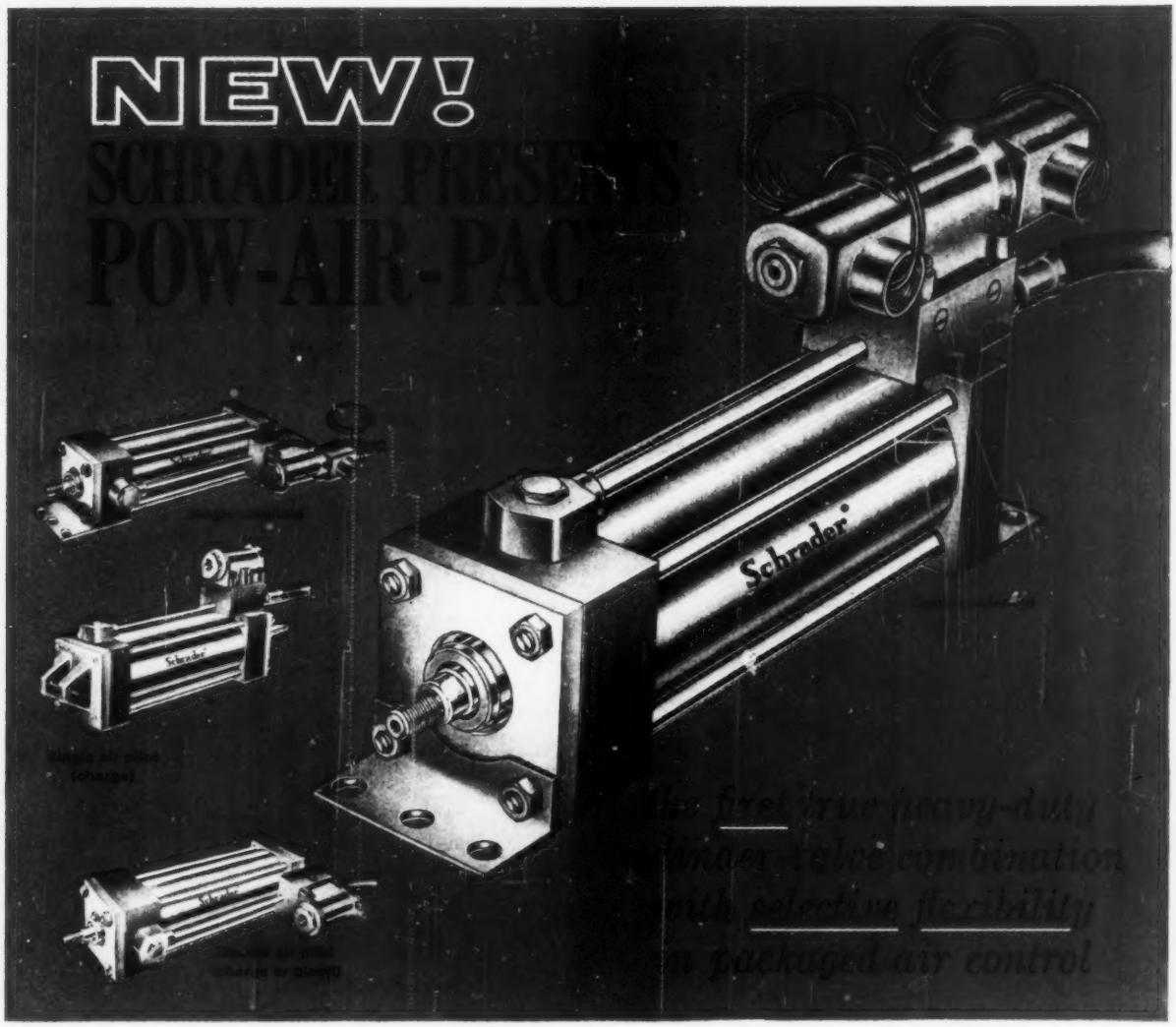

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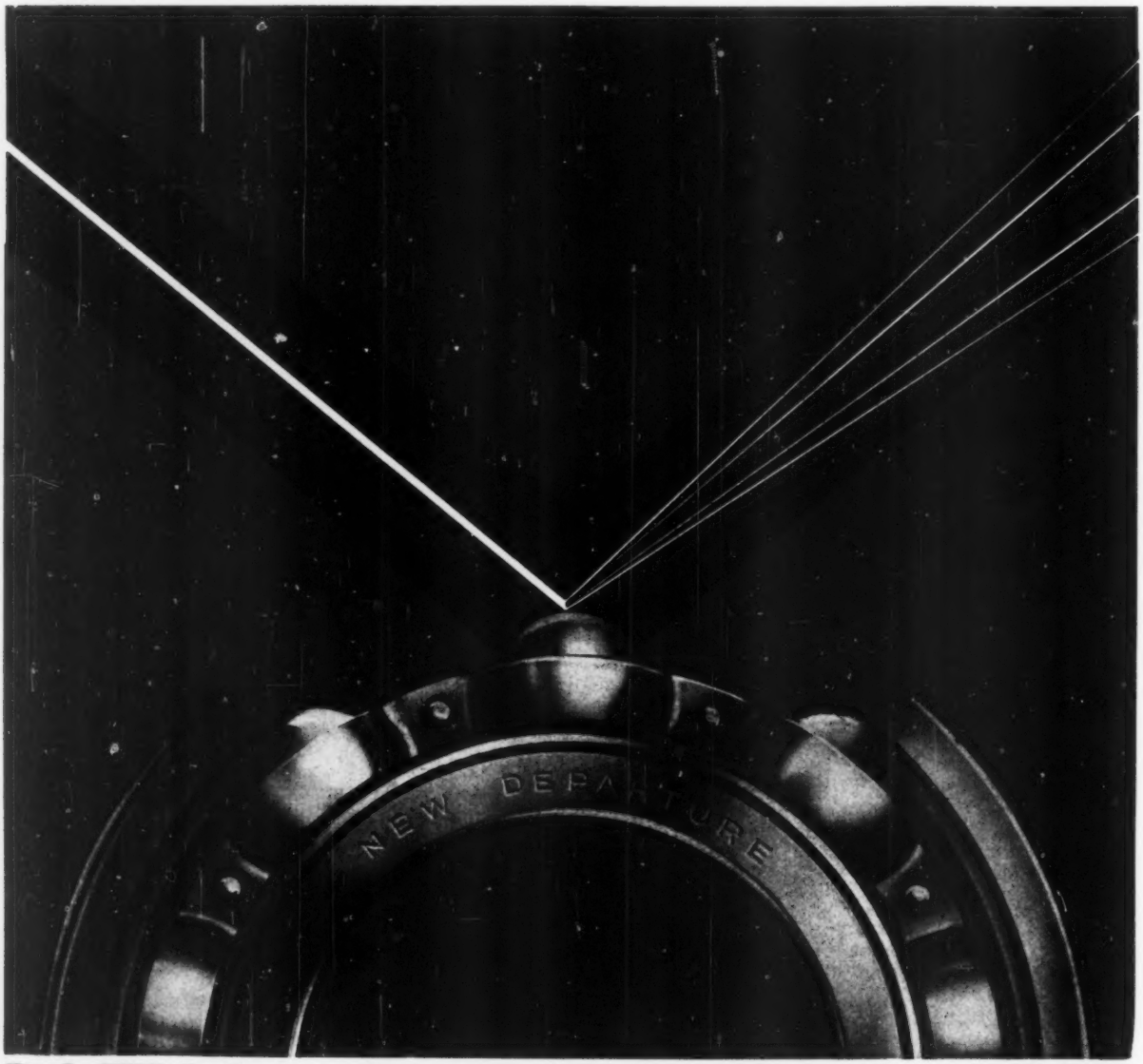

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HORIZONS

Santa meets modern times

"YOU KNOW," said Santa Claus to Rudolf, the reindeer, "they're fussing about you down on Earth. They want you to run backwards behind the sleigh. Something about international standards making red the color for tail lights, and people being confused by all this after they've been out sampling wassail bowls."

"Couldn't run backwards, deer me, no!" piped Rudolf. "Would belie that song they wail on jukeboxes starting six weeks or more before our annual trip. Even *that's* becoming a hazard, what with scientists, engineers, orbiting junk, Van Allen belts, and radioactive clouds to dodge. Our team really needs a headlight these days. Besides, fire engines have red lights in front. Hay, maybe you could get clearance as a fire engine. You're so important, according to all the windows and ads, you'd think you could get some sort of police card."

"Well, scarcely," said Santa. "You see, they much prefer me as an idea rather than a competitor. We give our presents away—the only requirement being that the children be reasonably good. That's not in line with commercial practice. And their psychologists have come up with a whole series of ideas: that I'm a father image, that I'm instilling bribery, that I'm a bad idea to teach kids because they'll expect a Santa Claus all their lives, that fables like me should be replaced by facts, and so on. Businessmen call me the next thing to Social Security and ally me with pork-barreling and Relief. The government calls me Big Business."

"Now, now," piped Rudolf, "don't worry about that. I was reading the other day that what's good for business is good for the world."

"Can't believe that either anymore," said Santa. "Lately, I've run into so many restrictions that it's getting hard to operate. I'm a monopoly, so they're talking of breaking *me* into competitive units. Then I have always used elves up here, and everybody knows they work best at night, but that's being called unfair competition by businessmen, and sweatshop conditions by labor down there. And the elves are beginning to fuss. They want to work an 8-hour night, and have fringe benefits—whatever they are."

"That reminds me," said Rudolf, "we deer were talking about portal-to-portal hay the other day, and extra hay for overtime. You know, this trip takes 24 hours, and we're transportation deer—or deer transportation, if you want to look at it that way."

"Yes," said Santa, "but it's only once a year!"

"That doesn't matter," said Rudolf, "that's part of the fringe benefits—extra pay for overtime and a four-day week."

"What's happening, I'll never understand," said Santa. "The elves and you talk of new-fangled ideas I've scarcely heard of—and in a traditional business, too. And I've always used non-colic paints, non-scratching materials, and safe designs for toys, but now I'm supposed to mark everything to prove it. Meanwhile, the toys are becoming so complicated, they're obviously for parents and not for children. 'Visions of sugar plums' indeed! Between parents, diets and mechanization, all I feel safe to turn out is a penny-operated Metrecal dispenser.

"I'll either have to cancel the annual trip or get some engineers, I guess," said Santa. "That's the rage on Earth. But they're scarce and getting scarcer, and most of 'em seem to be specialists in toys for grownups. What we need here is an all-around man who can design for children, then teach the elves how to make Noah's Arks, rocking horses and dolls that will compete with what they're turning out down there—rockets, satellites, missiles and mechanical monsters that fire 'em—pretty lethal in idea or operation. If I'm to continue as a tradition of good-fellowship, we can't stoop to that sort of thing, and with any reputation for reliability and integrity, our stuff has to work longer than five minutes and has to be interesting enough to the children that their parents can't break it up for them."

"Speaking of engineers, Santa, maybe you'd better get a couple to design you a rocket sled, so my red-nose problem would be solved," piped Rudolf. "Donner and Blitzen and the rest of us have reached retirement age anyhow. We deserve Christmas Day off like anybody else."

"Merry Christmas, is it?" asked Santa. "What happened to that basic idea anyhow? I can't even promise 'em all a good night!"

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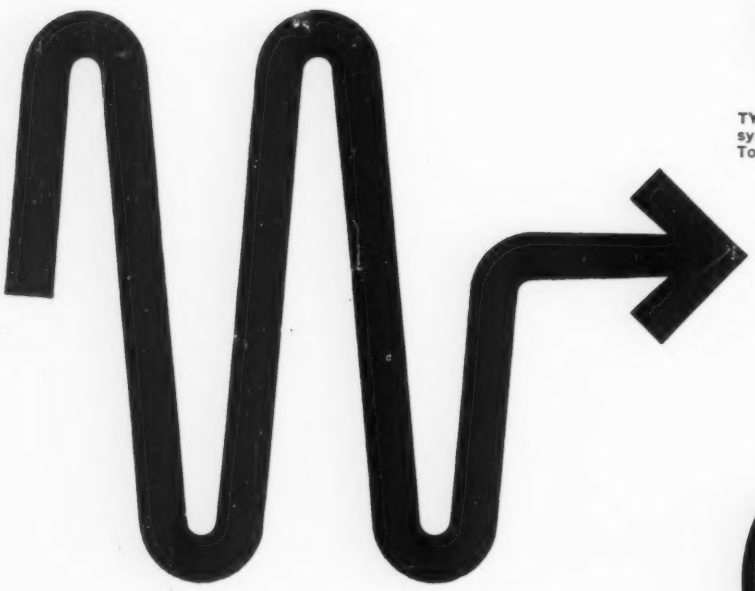
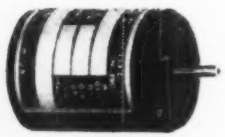
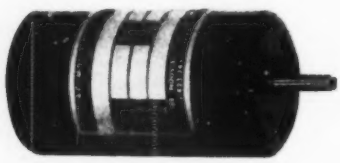
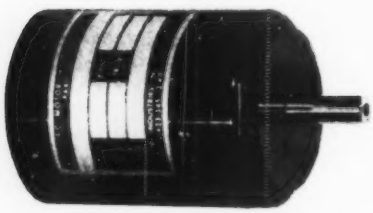




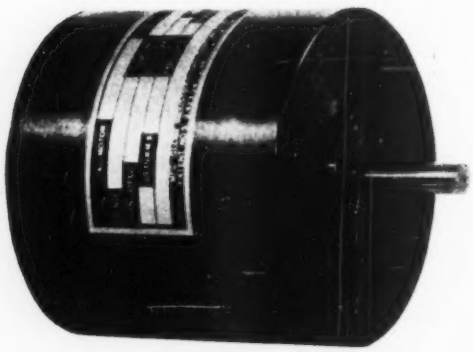
TYPE SC Sub-miniature motor rated .15 oz. in. max. sync. torque. Size: 1.07" dia. x 1.32" long. 2.4 oz. To 200 v. a. c. 2, 4, or 6 poles. 49 std. gear ratios.



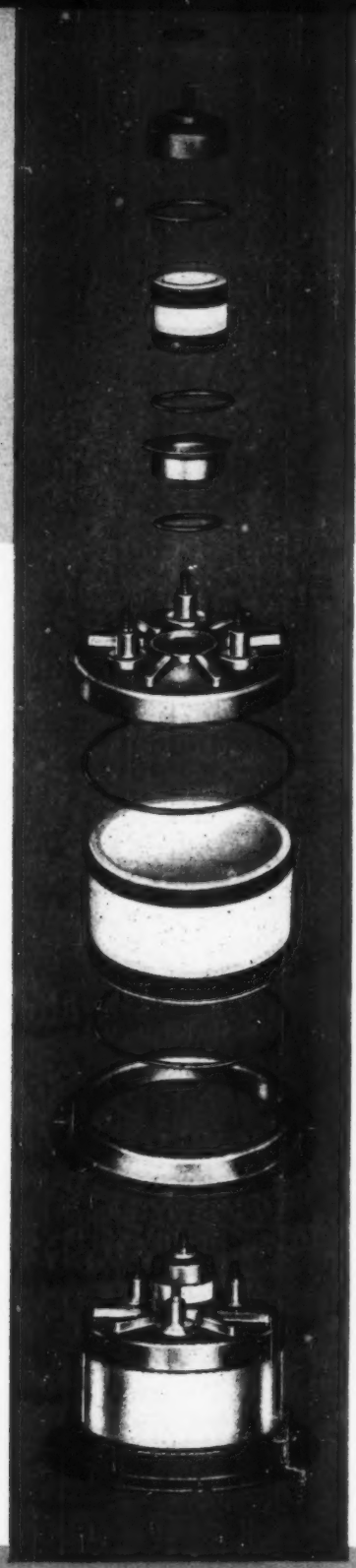
TYPE MC Miniature motor rated 0.8 oz. in. max. sync. torque. Size: 1¼" dia. x 2¼" long. 6.5 oz. To 200 v. a. c. 2, 4, or 6 poles. 101 std. gear ratios.



TYPE FC Small motor rated 1.6 oz. in. max. sync. torque. Size: 1 11/16" dia. x 2¾" long. 13.4 oz. To 200 v. a. c. 2, 4, or 6 poles. 101 std. gear ratios.



TYPE LC Small motor rated 10 oz. in. max. sync. torque. Size: 3¾" dia. x 3⅛" long. 53 oz. To 200 v. a. c. 2, 4, or 6 poles. Gearing to order.



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READER TO EDITOR

Headlights First

To the Editor:

I agree with Mr Stadnyk (PE—Oct 30 '61, p 14) that tail-light signals are a necessity, but glareless headlights are far more important.

My interest in automotive safety is well known to the headlight industry, The National Safety Council, State and Federal governments because I invented, designed, constructed and sold glareless headlights to the public between 1917 and 1922. Still, California laws will not allow the use of glareless headlights. A hunter is not allowed to blind a deer by his glaring headlights, but he can blind as many vehicle drivers as he pleases. Nor is the inspection of vehicles required by this state. And even a few blind persons have been given licenses to drive a car. Carnage on our highways is still our greatest problem—at the cost of an ignorant public—although Europe enjoys the use of glareless headlights.

—MILO C. CAUGHREAN
San Francisco, Calif

To the Editor:

The letter from Mr Michael Stadnyk, in your issue of October 30, concerning tail lights has merit. My thoughts along that line would add another feature he might work on. This is a signal light at the front of the car in parallel with his tail lights. Often, in meeting another car, or a car approaching at right or left, if one can see that this car is braking for a stop, or not braking, a moment of anxiety and perhaps some collisions may be eliminated.

I would like to see Mr Stadnyk include this in his setup.

—JOHN A AYCOCK
Rock Hill Printing & Finishing Co
Rock Hill, SC

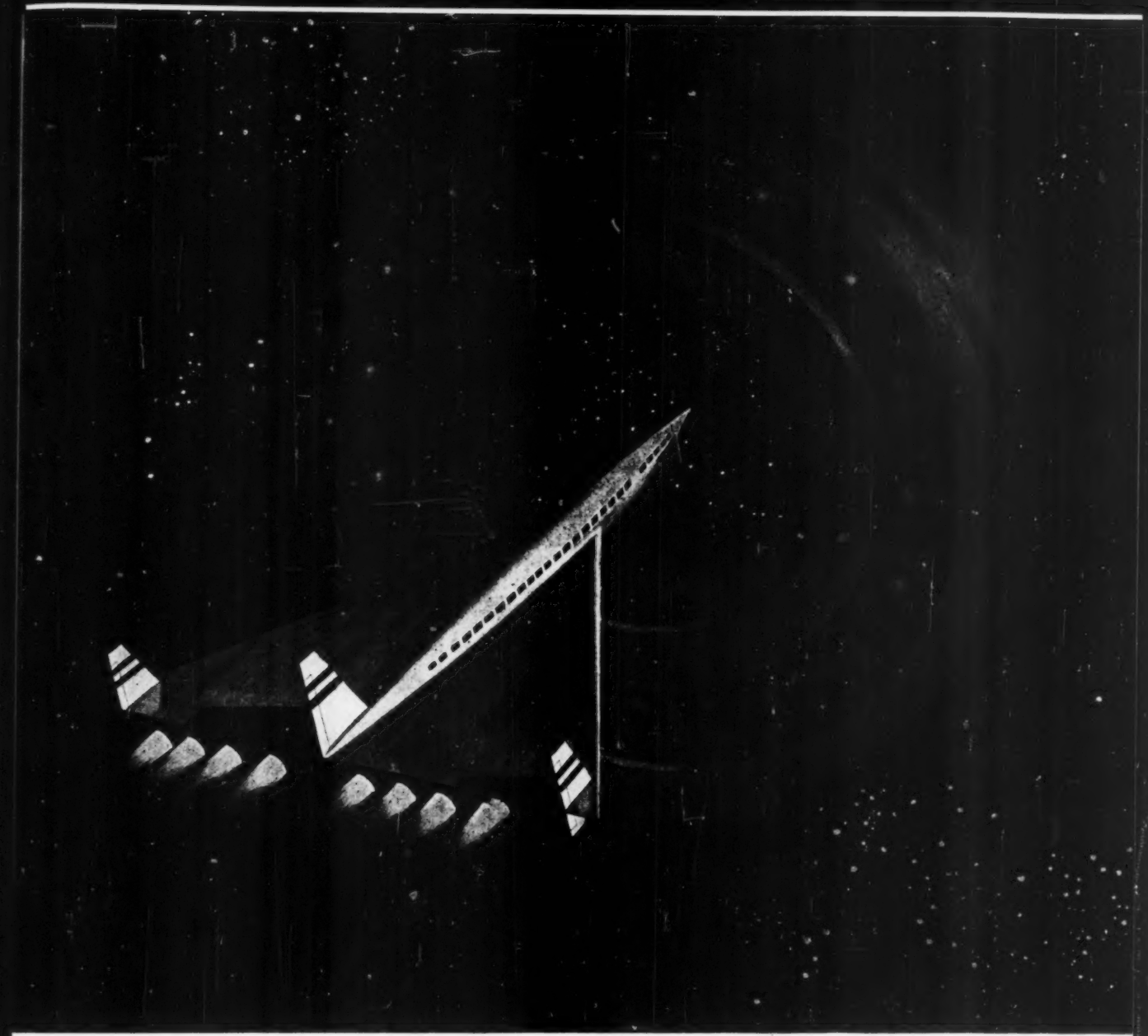
The hero was an ass

To the Editor:

I always enjoy the wit of your "Horizons"! In Nov 13, p 6, you discuss the question of who was the hero of the Battle of Tannenberg Marches. The solution is quite simple. The "Hero" was "an ass loaded with sacks of gold."

This solution about military heroes was stated about 2000 years ago by the famous Roman general, consul and, finally, dictator, Lucius Cornelius (Felix) Sulla (138—78 BC) who said that the best general in this world he knows is an "ass loaded with sacks of gold"!

continued, page 16



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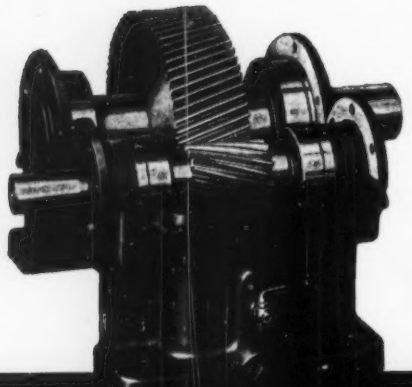

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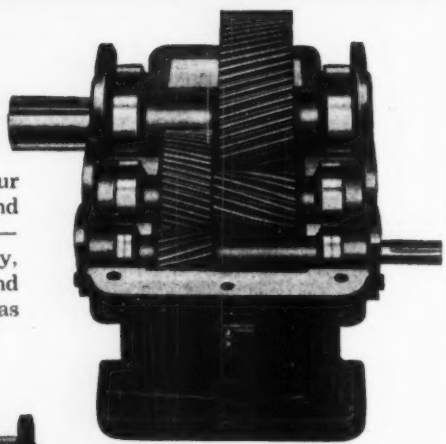

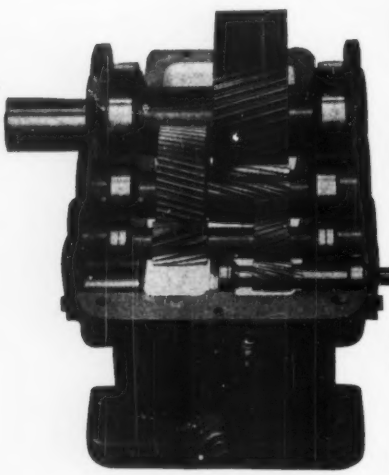

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READER TO EDITOR

In World War I, the German armies were usualy victorious over the Russian armies because a Russian colonel in charge of the Intelligence and Counterespionage Section of the General Staff was a steady host of "an ass loaded with sacks of German gold."

The real hero of the Tannenberg battle is thus the man who loaded the ass with sacks of gold!

On the Austrian Front, the Russian Armies were mostly victorious because the chief of the Austrian General Staff was a willing host of "an ass loaded with Russian gold," as it was found after the Russian Revolution.

Was the "ass" busy during World War II? Who knows? Too bad that the captured archives of the German General Staff were returned to West Germany without microfilming them, as William L Shirer states in his book "The Rise and Fall of the Third Reich." —SERGIUS D BROOTZKOOS

Washington 16, DC

COMING EVENTS

JANUARY

8-12 . . . . Society of Automotive Engineers, Automotive Congress & Exposition. Cobo Hall, Detroit

9-11 . . . . Institute of Radio Engineers, 8th National Symposium on Reliability & Quality Control, Statler-Hilton Hotel, Washington

24-26 . . . . American Society of Mechanical Engineers, 2nd Symposium on Thermo-physical Properties, Princeton Univ, Princeton, NJ

25-26 . . . . Univ of Wisconsin, Research Management Conf, Madison Campus, Madison Wisc

28-Feb 2 . . . . American Institute of Electrical Engineers. Winter General Meeting. Statler-Hilton Hotel, New York City

29-Feb 1 . . . . American Society Heating, Ventilating, Air Conditioning Engineers, Semi-annual meeting, Chase Park Plaza Hotel, St. Louis

30-Feb 2 . . . . Society of Plastics Engineers, 18th Annual Technical Conference, Penn-Sheraton Hotel, Pittsburgh, Penna

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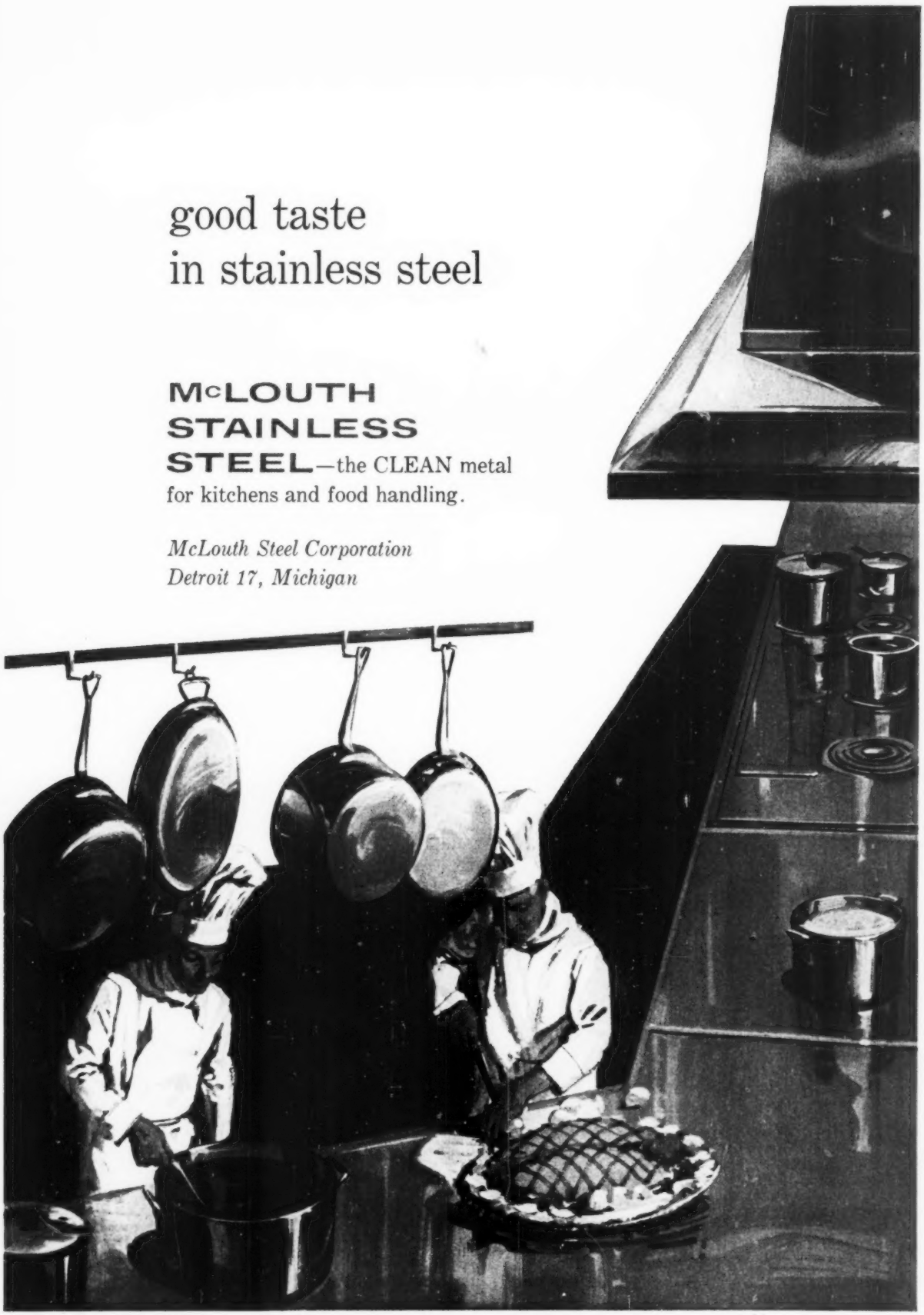
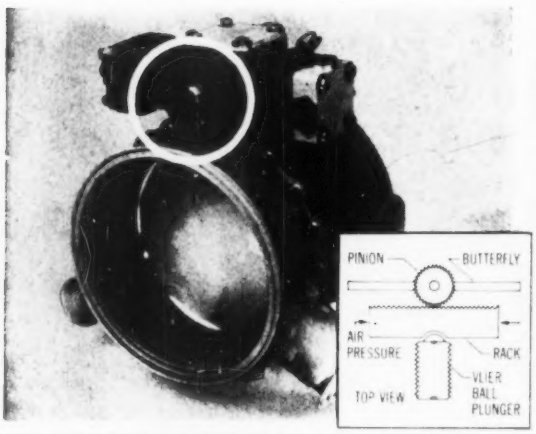


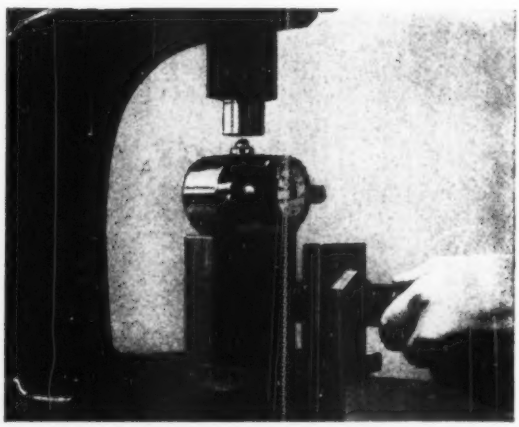
Practical Design Tips

No. 6 of a series

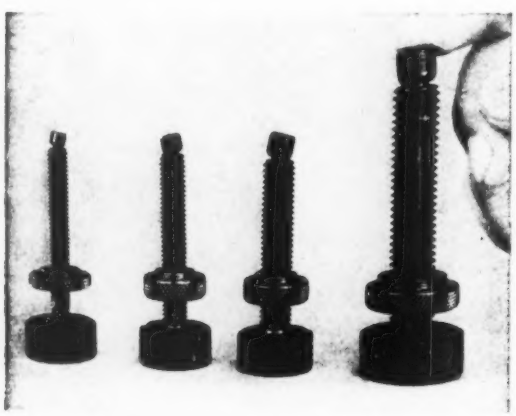
If the profit squeeze is making you look for new ways to reduce costs, look into Vlier products such as those shown below. Hundreds of companies are using these simple, standard parts to replace complicated, specially-machined devices—usually at a fraction of the cost.



SPECIAL VLIER BALL PLUNGER used on this Hermetic Barrier Valve detents on a rack which controls a pinion, which in turn, operates the butterfly. Air pressure forces rack out of detent, opening or closing valve. Plunger, therefore, acts as a positive stop until air pressure is great enough to force shaft past detent. Vlier Ball Plungers are available as standards in sizes from 4-48 x $^{3}/_{16}$" to $^{5}/_{8}$-11 x 1". Various end pressures. Specials on quantity orders.



SPECIAL VLIER SPRING PLUNGER, shown in test fixture, has laminated phenolic plunger to conform to MIL-P-79B (Type GMG). $1^{1}/_{4}$" plunger travels .890"; absorbs side load of 105 ±20 pounds. Vlier can provide spring-loaded devices with various diameters, end pressures, plunger lengths, and made of materials to meet your specifications.



NEW CONTROLLED-TORQUE TOOL incorporates a swivel-pad on the screw end to protect surface of part being held. Pad swivel 7½° in all directions to accommodate off-angles. Has unique ball-joint construction for smooth operation. Named the Vlier Torque Thumb Screw Swivel-Pad Clamp, they are available as standards in ¼-20 x 2¼", $^{5}/_{16}$-19 x 2¼", $^{3}/_{8}$-16 x 2¼" and ½-13 x 3".

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DEVELOPMENTS TO WATCH

Structural engineers are exploring all sorts of new ideas in their hunt for stronger, lightweight structures. One is a new type of corrugation that's said to be an improvement in both physical properties and cost as compared to honeycomb sandwiches (*PE—Nov* 27, *p* 40). Another takes its cue from the internal structure of crystals. R. W. Kraft of United Aircraft Corp suggested this one at a recent ASME meeting.

Of the various crystal systems (face-centered cubic, body-centered cubic, etc), he notes, the arrangement displayed by the diamond is one of the lowest in density. It has an internal structure which is essentially a regular tetrahedral arrangement of spheres.

By an extension of this system, in which four smaller spheres are arranged inside of each primary sphere, an even lower density can be obtained.

But a system of spheres would not be entirely desirable from the point of view of shear and tensile strength. So, Kraft suggests substituting rods which extend, in the packing arrangement, from center to center of adjacent spheres. In effect, these rods represent the carbon-carbon bonds in a diamond crystal. When this is done, each packing arrangement produces a three-dimensional truss with different degrees of cross bracing.

The result, he says, is an unusually rigid and lightweight structure, well able to bear both shear and tensile loads, and simple and relatively easy to construct.

Fastening systems are getting a close look, too, in the hunt for stronger structures. **The smaller the rivet, the better the joint**—at least as far as fatigue resistance is concerned. Tests at Bolt, Beranek, and Newman indicate the increase in fatigue resistance with reduction in rivet size is a good deal more than might be expected in some cases.

C. I. Malme, C. M. Gogos, and I. Dyer of BBN told the Acoustical Society of America that tests at three strain levels of three rivet sizes (0.125, 0.250, and 0.375 in. dia) showed a range in fatigue life of 0.4×10^5 to 4×10^5 cycles, with fatigue-strain concentration factors ranging from 1.5 for the smallest rivet to 1.7 for the largest. The tests were made on a simulated 2024-T3 aluminum structure (a 2 x 3.5 x 0.032 in. sheet with three aluminum bolts to simulate a clamping row of countersunk rivets). The structure was cantilevered in a siren test duct and excited at its fundamental resonance by plane waves of sound. Nominal strain at the rivet line was set by controlling the amplitude of motion at the end of the cantilever.

• • • •

Power plants and power sources continue to make news. **Wireless transmission of power**—beaming electrical power across the country or out to space as radio waves are now transmitted—**may soon be a reality.**

Both US and USSR researchers are working on the problem; and the Soviets, at least, claim substantial progress. Antennas with apertures of "thousands of square meters" are now being built, and transmitter tubes are being designed which "will be capable of delivering hundreds of kilowatts of microwave power." The Soviets are toying, too, with the idea of flying a pilotless helicopter on power radiated from the ground. Soviet scientist A. M. Pokras, writing in *Radioteknika* (v 16, #2) envisions a wireless transmission system consisting of two antennas, ellipsoid in shape.

With such a system, he believes, the transmission efficiency will be 80% or more, as compared to an efficiency of only 20% for a periscopic-antenna system using two plane mirrors 2 ft apart, operating on a 3-cm wavelength.

As our own army researchers point out, methods for transmitting electrical (electromagnetic) energy through space are known. Energy is transmitted through

"space" (the air gap) between stationary and rotating members of generators and induction motors. Since, theoretically, there is no energy loss attributable to the "space" in such cases, the efficiency of electromagnetic energy transmission should be 100%.

The trick is to develop methods and equipment to focus and direct large quantities of power from a point of generation to a predetermined point of reception. It's quite a trick. But there is reason now to believe it can be done.

Solar battery output can be increased as much as 30-fold, and conversion efficiencies more than doubled, by taking advantage of new plastic lenses.

Tests at Kobayashi Institute of Physical Research (Tokyo) indicate that, by focusing solar light on the cells with the aid of these low-cost Fresnel-type step lenses, a power output of 0.4 mw can be achieved—16 to 32 times larger than the present average.

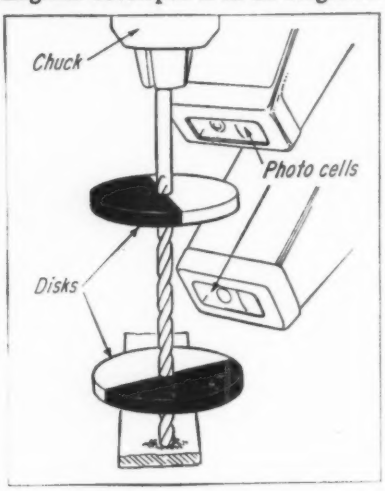
By combining a step lens and a step prism with a specially designed photoelectric cell, even greater efficiencies may be obtained. Such a combination of optical elements would produce a spectrum of radiation. If this were applied to a series of photovoltaic cells or, better still, to a photovoltaic cell having different spectral sensitivities along its surface, conversion efficiencies on the order of 39% may be possible.

These plastic lenses and prisms, now available commercially from US as well as Japanese manufacturers, are simple in design and surprisingly inexpensive. Step lenses of the Fresnel type are being produced in Japan of acrylic plastic at a cost of about 2½¢ a square inch; and, they say, the step prisms, which are simply transparent plates with a corrugated surface that acts as a prism, can be produced at equally low cost.

• • • •

In instrumentation, there are novel systems for measuring everything from the torque on a shaft to the speed of a bullet.

The system for measuring torque is based on the indication of torsional twist under dynamic loads. Dawe Instruments of England developed it as an outgrowth of research on its own transistor phase meter—an instrument that measures phase shift in electrical networks. The idea is to obtain two out-of-phase signals and compare them. This is done by a photocell system that takes its cue from white lines marked on the device being measured or half-white disks attached to it (see sketch).



Twin photocells pick up signals from the marks and feed the signals to a phase meter. As load is applied and the shaft twists, the amount of twist is indicated directly in angular degrees. Then, from the geometry of the shaft and the elastic modulus of the material, the applied torque can be derived.

Miniature coils, only a few millimeters in dia, that are capable of handling pulsed magnetic fields on the order of 100,000 oersteds, have been built at GE Research Lab. They're being used for experiments on microgram-sized magnetic speicmens —single crystals. And, says R. W. De Blois of GE, they require a power supply of only a few joules capacity and can be used in unconventional places (inside a

pressure cell for combined high-pressure, high-field experiments, for instance); and can obtain useful data on specimens as small as a microgram.

The latest model is only 2.62 mm long, 1.70 mm in outside diameter, and contains 411 turns of 0.002-in. insulated copper wire in ten layers. Six counter-turns are wound around the middle to flatten the field contour. The field at the center is calculated to be 1800 oersteds/amp.

GE has no thought of offering these particular coils commercially. But, as De Blois points out, they prove that huge, expensive installations are not required for high magnetic field research; and that useful measurements can be made on samples that are almost too small to be seen.

A new kind of radiation detector is under test by Army Signal R&D Lab engineers. It consists of a tiny titanium tube (¼ in. dia; ½ in. long), coated on its inside surface with magnesium oxide (in an oxide-oxalate mixture), and equipped with a central electrode.

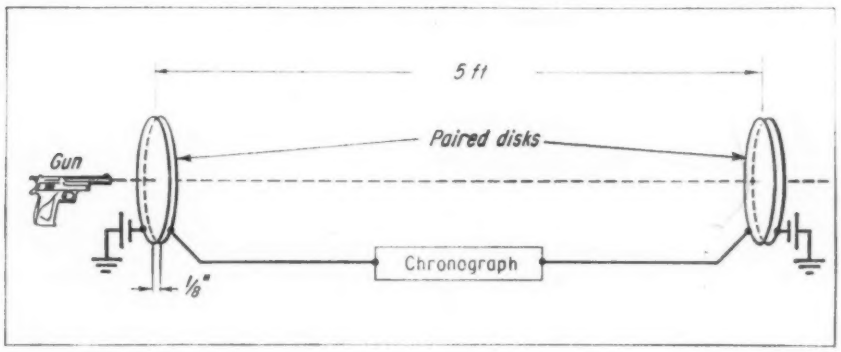
When the device is exposed to radiation, electrons are emitted from the titanium envelope and multiplied by the MgO layer. This, R. G. Saelens of Ft. Monmouth says in a report to the American Physical Society, permits a high yield from a very small unit; and it shows excellent response to brief (5 microsec) pulses of backscatter radiation at doses from 10^4 to 10^6 r/sec. The device is now undergoing additional tests in the General Atomic linear accelerator.

An electrically heated platinum film on a water-cooled glass tube serves as the sensing element in a new system for measuring temperature, velocity, or variations in composition of gases. Like a conventional hot-wire anemometer, it will respond to the external mass velocity and is sensitive to the transport properties of the gas. Dr P. L. Blackshear of the Dept of Mechanical Engineering at U of Minnesota, where the device was designed, says its advantage is that it can be used in higher temperature environments—even for electrically heated plasmas.

The sensing element tube is Pyrex glass (0.005 in. OD; 0.003 in. ID; 0.08 in. long), coated on the outside with a layer of platinum about 1050 A thick. Coolant flows through the center of the tube, at high enough pressure to prevent boiling.

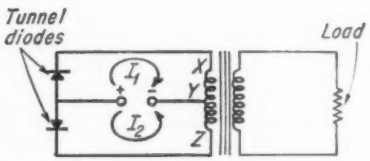
The metallic film is kept at constant resistance (hence at constant temperature) by the power supply, and the heat flux from surface to water is constant. The heat flux between the surface and the external flow depends primarily upon enthalpy differences, the flow velocity, and the transport coefficients. When one of these parameters is changed, the heat flux across the surface changes and thus the power required to keep the film at constant temperature changes. Thus a measurement of any one of the three factors may be obtained; and all three may be monitored by providing three sensing elements.

Bullet speed is being measured at Hyderabad Science Society, Andhra, India, by an easy-to-build system that uses paired, short-circuiting disks to start and stop a chronograph. Two pairs of disks (about 6 in. dia), are mounted, about 5 ft apart, in the firing line (see diagram). Between each pair, there is an air gap of



about ⅛ in. One plate of each pair is connected to a dry cell; the other to a chronograph. As the bullet pierces the first pair of disks, it shorts the circuit and starts the chromograph. As it pierces the second, a short again occurs and stops the clock. The disks are so thin they do not interfere appreciably with bullet speed, and the time can be measured with an accuracy of about 5 microsec.

Two tunnel diodes and a small transformer can be combined to provide a simple static inverter for stepping up the voltage of such devices as fuel cells and thermionic and thermoelectric converters. These new power sources generally supply high current; but it's dc at low voltage—too low for practical application in many cases. With the new inverter, J. M. Marzolf of Naval Research Lab claims voltages can be stepped up from the 0.2 range to practical values; and, he says, "the output is a very good ac square wave."



The transformer is wound on a square loop magnetic core; and the tunnel diodes are of the highest-peak-current type.

In a progress report soon to be published as NRL 5709, Marzolf describes several circuits that have been constructed, using various size tunnel diodes; and notes that the simplicity of the unit and the high quality of the square wave produced may also make the device useful as a square-wave signal generator.

• • • •

Analyzing with radioisotopes is explained clearly and with excellent illustrations in a 32-page booklet offered free of charge by Nuclear-Chicago Corp. It tells how to put those activated atoms (*PE—Nov* 13, *p* 79) to work on engineering R & D problems.

To help youngsters build their own electrical systems—motors, batteries, and buzzers—the National Electrical Week Committee has prepared a set of attractive leaflets telling exactly what's needed to build simple, rudimentry devices. The motor, for instance, is made of wire, paper clips, and thumb-tacks. The battery calls for a transformer, a few pennies and dimes, a compass, a lemon, blotting paper, an old bell battery and ammonium chloride. The leaflets were designed for mass purchase, and distribution during the forthcoming Electrical Week. However, PE readers may purchase single copies at 10¢ each (stamp or coin) from National Electrical Week Committee, Suite 306, 407 N 8th St, St. Louis 1, Mo.

Junior can build a world of his own, too—in 30 minutes. A 42-piece, snap-together "World Maker" Kit has high-impact polystyrene globe sections and land masses that can be assembled into a 12-in. sphere that revolves on its own stand, and can be used to study time zones, latitude, and longitude. A geography booklet accompanies each kit. The price: $11.95. The manufacturer: Eldon Industries, Inc, Hawthorne, California.

A new gadget to tempt the home hobbyist is a magnetic thumbtack dispenser and inserter. It's a hollow plastic handle much like the plastic handles used on screwdrivers and about the same size. But, where the driver would ordinarily be attached, this unit has a magnetic cap that picks up and holds the tack so it is easily positioned and pressed into place. The handle will store 36 tacks; and the cap can also be used to pick up pins, clips and needles. Hollis Co, 1133 Broadway, New York 10, N. Y., is the distributor. The price: $1.00 postpaid. **—ARG**

You'll need new skills, viewpoints

What it is to be a boss

Most engineers think sooner or later of switching from technical work to a managerial position. Are you? If so, here's what you can expect.

ROGER K CRANE, chief engineer, American Technical Co

ABOUT THE AUTHOR

Our question to Roger Crane about his career brought this cogent statement: "I'm a graduate engineer with an ME degree who has worked in product engineering, power plants, hydraulic systems, etc. About five years ago I got into management and went through much of the experience described in the article. Since then things have been easier. For the last several years I've done management consulting for a variety of technically oriented firms."

YOU, and only you, can answer the question: Should I switch from engineering to management? To answer it accurately you must know yourself. You must know what you want in life, where you want to go, how much effort you're willing to put into your career.

Suppose you do change to management. What new problems will you meet? What new skills must you develop? How will your rewards compare with those for a job well done in engineering? Let's see:

Specific to general

In engineering you work with specifics—weight, length, height, pressure, force. In management you work with generalities--supervision, arbitration, sales, delegation, negotiation. Engineering has its neat slide rule, graph paper, handbooks, laboratory tests, and formulas. After a few years you become a specialist in one or two areas. These become comfortable, well-defined boundaries which give you satisfaction and a livelihood, and allow you to contribute to technology. You always know where you stand because you can measure results accurately. And you can be as exact as you wish. Your tools are known; your theories can be tested and proved by accepted methods.

Management, too, has its tools. But they are crude compared to the precise tools of engineering. Why? Because the problems of management are affected by so many unpredictable variables, human, economic, and political.

So the first difference you'll find between engineering and management is one of specifics vs generalities. In engineering there is almost always an equation you can use or develop. In management there is hardly ever an equation you can apply.

During your first few months in management you'll find yourself trying to plot curves for or to tabulate non-measurable data. After several attempts you'll give up. And then you may say to yourself, as one new engineering manager did, "Everything here is gray; there's no right answer."

That's just it. There isn't any "right" answer. There's only a workable answer that may be right today and wrong tomorrow. Once you realize that, you'll throw away your graphs and tables. You'll mentally balance yourself like a boxer on his toes, ready to change with external conditions. For your world is no longer neatly bounded by slide rules, formulas, and handbooks. Instead it has no real boundary and its elements are constantly changing.

People, people everywhere

In engineering you figured a beam, designed a new machine, or wrote a specification. In management you delegate work, settle disputes, approve expenditures for projects whose outcome is a gamble. But always there are people.

Some engineers work on a project for weeks and have little or no contact with other people. As part of a management team you can hardly work five minutes without dealing with other people. And the people are all kinds: happy, angry, disappointed, engaging, healthy, sick.

You must deal with them in hundreds of ways. You will delegate work, settle disputes, reprimand, explain, answer questions, decide between alternatives. In management you may spend as much as 80% of your time talking with people. It isn't always easy, particularly when you're trying to convince, sway, or influence them.

Probably the most difficult part of changing from engineering to management is learning to cope with the irrational verbal and written demands of outside people. Your first reaction

as an engineer will be to search for a logical, factual answer to complaints or insistent demands of someone who has little knowledge of your business. After a few attempts you'll find that a completely logical and factual answer is seldom satisfactory. Why? Because you're dealing with human beings. You'll push your engineering books to the corner of the bookshelf and replace them with a few books on psychology and human relations. Once you do this you're well on your way to becoming an educated manager.

Even some of your managerial associates may puzzle you at first. For instead of operating in accordance with equations, theorems or physical laws, they seem to operate by means of some strange, unseen waves. Actually, there's nothing strange about their ways. These experienced managers are constantly analyzing, judging and evaluating business situations. And they're rapidly altering their opinions, concepts and theories as they meet new situations.

You, too, must learn to think faster. Many of your quick decisions may be wrong. But instead of fretting, as many engineers are inclined to do, you must rectify your decision and go on to your next problem. For in dealing with people instead of facts you seldom have time to spend days and days analyzing a situation. People are often hurried; there's always a phone ringing; someone is impatiently waiting in the lobby to see you.

Your reading will change

Today, as an experienced and skilled engineer, you probably read a dozen or more technical magazines every month. You study all kinds of good articles—design procedures, maintenance operations, new equipment, etc. You're looking for new ways to do a better engineering job. Specific procedures, exact details, and proven values are of greatest importance to you. These are data you need ways to do a better engineering job.

Change to management and you'll alter your reading habits. You'll still read the same magazines, plus a few more, but your attitude toward the subjects will change. Instead of trying to understand every step in a process or procedure, you'll look for the results. Your eye will seek out hourly production rates, costs, manpower needs. You'll mark an article for the assistant chief engineer with: "Jim, please check this process; it might save us some money on the new design." And Jim will check the details while you present the idea to upper-level management.

Personnel columns will mean more to you in management than they did in engineering. You'll seek out the news of promotions, retirements, transfers. Because once again, your main concern is with people and their effect on your firm's business.

You'll read different books. Texts on finance, production, sales, speech-making, patents, inventions, human relations, and publicity will nudge your engineering handbooks and texts aside. You'll seek general methods—not specific procedures. You will begin to operate by "feel" instead of by fixed formulas or rules. The generalist aspects of your character will emerge to take over and push the specialist training of your engineering career into the background.

You'll make speeches

Management solves many of its problems in meetings, conferences, and panels. You'll be called on to speak. In a company meeting you'll be expected to explain, defend, propose, excuse, or present ideas of all kinds. Much of your future will depend on how well you act at these gatherings. For higher-level management will not only be judging your business decisions—they'll also be evaluating you as an individual. So to succeed you'll have to learn how to talk and think on your feet.

The company meeting is not the place for nervousness, slips of the tongue, or immature self-centeredness. So get to know yourself better. Remember that your engineering training is a priceless asset. As an ex-engineer you'll be respected by non-engineering management. They'll look to you for technical opinions, for judgments involving production, design and maintenance. So forget your nervousness; concentrate on what you're saying. But don't try to impress them with your personal intelligence and special education. Slice your opinion to the bone; give results, costs, advantages. Omit long-winded step-by-step procedures. These take up valuable time. Remember: you are now a generalist, not a specialist. Use these hints and you'll soon see a new you emerging—a valuable and respected you, a real asset on any management team.

You'll also speak in public to audiences of all sizes. And you'll be frightened at first—everyone is. But stick to it. Prepare your speech early; practice long. Get yourself several good books on public speaking. If these don't give you what you want, seek professional advice. Today there are speech-training classes in almost every large city.

Your success as a manager will depend, to a large extent, on your ability to motivate other people. So learning how to speak well before others is one of your most valuable tools. Start developing your speaking skill today.

Your thinking will change

As part of the management team you'll think differently. Instead of being confined to a single engineering project, your viewpoint will be company-wide. Over-all profits and losses will be of extreme importance. Also, the financial performance of your own department will be a daily concern. You'll begin to see how your efforts affect the entire company. To many ex-engineers there is nothing as challenging as guiding a group of people along the path to high profits.

Your methods of thinking will change too. You'll find that you must:

- Think of others first
- Think ahead of your present problems
- Think of many alternatives
- Think in terms of selling
- Think of new-business sources
- Think while listening to others
- Think to get to the core of problems quickly

Much depends on your firm, its products, and your new job. But you must realize now that, in many ways,

Do you really want

Management is a treadmill. If you choose to get on, you can't get off until you fall off or reach the end. It means longer hours, a constant condition of overwork, social engagements that are actually business contacts, community committees and boards, endless details and meetings, dull work like budgets and reports instead of engineering. You'll read and hear much more and enjoy it less, much of it in fields in which you're not now interested. Your loyalties will be fixed—the company comes first—so,

your thinking must change if you are to succeed in management.

Don't resist these new thinking patterns when they are introduced to you. If you do, you'll be inefficient and the change from engineering to management will be a painful process. Remember—you must wholeheartedly accept your new environment. If you do not put all your energy and skill into the new tasks you face, your road will be rough and full of disappointment. So you must learn to think as a manager.

You'll train people

As part of the management team you'll have the problem of training people for new or different jobs. At first your training duties may be no more than instructing a secretary about her job. But as time passes you may be called on to train people for more responsible positions. When faced with this task you'll begin to realize the importance of right thinking, ability to handle people, and good speaking habits.

Training others can be one of the most gratifying aspects of management. It gives you a chance to pass your experience along to others for their ultimate benefit and the benefit of the company. And the questions and discussions that arise during training sessions will open new vistas of self-knowledge and job skills to you. You will see, more clearly than ever before, that the human factor is the most important single element managers must handle—every day of the year.

Human relations

Many firms now have clinics in human relations for all new management personnel—particularly ex-engineers. The need for these clinics is widely recognized. And there isn't one progressive firm today that overlooks the importance of human relations. Why? Once again, management is primarily the function of getting the best from people with the least effort and friction. Here are six rules of human relations that will help smooth your switch to management. Start using them today—they'll save you much misery and wasted effort in any job and in your private life.

1. Express and show interest in people and their problems
2. Be as impartial as you can in all dealings with people
3. Treat everyone as an individual
4. Show appreciation whenever it is deserved
5. Be firm and fair in dealing with others
6. Look for what others can do, not for what *you* want

In dealing with people at work, keep their needs foremost in your mind. What do men and women want at work? Studies show that almost all of us want recognition, fair pay, security, good working conditions, agreeable supervisors, a chance to advance, important duties, and treatment as individuals. Keep these needs in view when dealing with other people. They are often the key to vague complaints, poor work, absenteeism, and other problems. As long as you are in management your dealings with people will never end. Cultivate good human relations and you'll solve more problems faster.

Learn how to delegate

To the new manager, the biggest problems of his day are those related to giving orders to others. Orders must be given. But to be effective, your orders must be delivered clearly, concisely and pleasantly. The secret of giving effective orders is to build enthusiasm in the person receiving them. You can't build enthusiasm by giving a lecture, threatening, or shouting. You build job pleasure and willingness in others in two ways: (1) by genuinely feeling this way yourself, and (2) by being friendly and courteous to your associates at *all* times—not just when giving orders.

Watch the successful managers around you. Most of them are well-liked and happy people. They have a ready grin; they tackle their work with enthusiasm and gusto. Their spirit infects their associates; theirs is a happy "shop". And when they give an order it is carried out quickly and efficiently. So learn now to delegate successfully—you'll find that it will be the most valuable tool in your management kit.

A new creativity for you

In engineering you cracked your mental whip to develop a new machine, solve a knotty vibration problem, or design a new process. The more creative your ideas, the greater your success as an engineer.

Much the same is true in management. But your creativity will run in different channels. Your ingenuity will help you search out the motives of other people; it will take the pulse of economic and political situations. As an engineer you may have neglected financial and business news. As a manager you will be sensitive to the many complex factors that affect your business. And the creative efforts you give to your job will include these complex elements, in addition to any technical factors you must consider. The challenge of management will open a whole new field to your mind. It will stimulate and exhilarate you much like a challenging engineering problem.

Morale will mean more

Morale on engineering projects varies considerably. In some firms the morale is high at the start of a new project. As work progresses, there may be a loss of interest; sometimes there is a tedious atmosphere about the whole effort.

This may not occur in management. Here there is a steady push, a constant grappling with new and changing problems. So your morale may stay on a higher plane. And to get the best from your associates you'll try to build their morale. In doing this your own enthusiasm will increase. The atmosphere will continuously stimulate you to better effort, higher efficiency, and greater skills.

EDITOR'S NOTE: For the management point of view on this problem, see "Which Road Up—Technical or Management?"—PE, Aug 14 '61, p 31-40, also available as a free reprint from Reader Service.—*E J Tangerman*

to be a big shot?

in providing your wife and children with a "better life," you'll be subtracting an increasing amount of yourself for travel and officer overtime. Your neck is always out and the competitive axe is sharp—from above, below, and both sides. You can't be affable or likable to your employes. You'll be constantly insecure because of politics, have to take sides in obscure situations, have to be restless and bullheadedly persistent. If these things, the money and the status attract you, go ahead—and luck! —ED

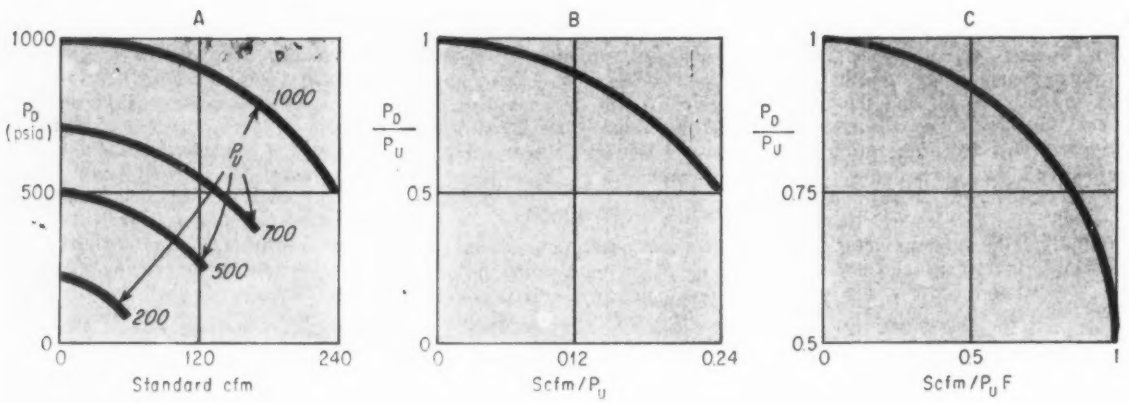
Charts simplify calculation of

Airflow in components

Flow, flow factor and pressure loss in valves and fittings can be determined easily with these nomographs and conversion charts.

DOMINIC J LAPERA, design engineer, Marotta Valve Corp, Boonton, NJ

What is the flow factor?



Gas or airflow through a pneumatic component may be fairly approximated with this relationship:

$\text{scfm} = \text{constant} \times \sqrt{(P^2_U - P^2_D)}$

where the constant depends on passage configuration, friction, and inlet temperature; P_U and P_D are upstream and downstream pressures, psia. Scfm is actual flow in cfm converted to "standard" conditions—14.7 psia, 68 F. Although the equation does not represent isentropic flow, and assumes considerable loss in stagnation pressure, its convenient mathematical form simplifies manipulation and the error will probably not exceed 5 to 10%. Test results can be plotted in three ways. Curves in *A* are flow data in scfm for a typical component. Curve *B* is from the same data converted to single curve by dividing by upstream pressure. Curve *C* is from the same data, further converted to "normalized" form by dividing by a defined flow factor, *F*, that is a measurable quantity.

Flow factor, *F*, is the ratio

$$\frac{\text{flow (scfm)}}{P_U \text{ (psia)}} \quad \text{when} \quad \frac{P_D}{P_U} = 0.5$$

The constant in the flow equation equals $F \times \sqrt{4/3}$, therefore the normalized equation for curve *C* becomes

$$\frac{\text{scfm}}{P_U \times F} = \sqrt{(4/3)} \times \sqrt{(1-(P_D/P_U)^2)}.$$

or

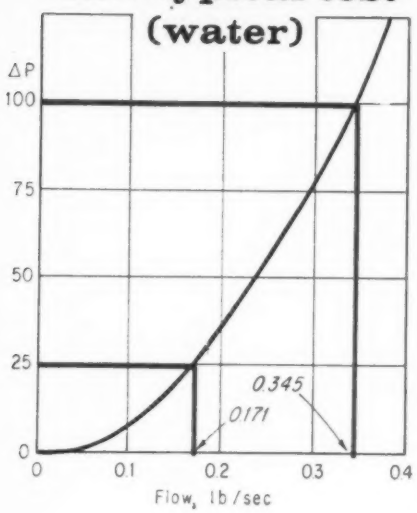
$$Q = P_U \times F \sqrt{(4/3)} \times \sqrt{(1-r^2)}$$

This variation of the NBS equation has proven to be a better approximation of actual flow:

$$Q = P_U F \sqrt{(8/5)} \quad \sqrt{[r(1-r)(3-r)]}$$

It is the mean between the $\sqrt{(1-r^2)}$ relationship and adiabatic expansion. Author Lapera used the mean equation to develop his flow nomograph, Fig 5.

1a..Typical test (water)



ESTIMATING airflow and pressure loss through a component in a pneumatic system is tricky for two reasons: pressure-loss data are expressed differently in different catalogs (*Fig 1a above is just one of the ways*) and subsequent conversion calculations are likely to produce errors; and flow is affected by gas properties.

This article helps solve both problems. The first, differences in catalogs, is handled by providing simple charts for direct conversion from catalog flow constants to the National Bureau of Standards flow factor, *F*. The NBS flow factor is widely accepted as a standard, and the method in this article is based on it. A brief summary of the NBS method is given on the facing page.

The second problem, effects of gas properties on flow, is handled by first converting the gas flow to an equivalent flow of air at standard atmospheric condjtions (here chosen to be 14.7 psia, 70 F). Charts and tables based on standard air simplify conversion and eliminate that source of error.

The over-all procedure for calculating airflow, starting with the catalog or data sheet and producing a numerical answer, is given in the accompanying series of charts and instructions. They are in proper sequence to take care of *all* problems; just skip the charts that don't apply to yours. Answers are given in units of flow, pressure-loss, or flow-factors; starting with any two you can easily read off the third.

Only a single pneumatic valve or component at a time is considered here. However, piping and system calculations based on the same NBS

1b..Effective orifice, D_o

Effective orifice diameter is derived from performance curve of water flow through a component as follows: On the water-flow-test locate any convenient pressure drop and find the corresponding water flow rate *W*; locate this *W* value on the nomograph and extend a line from that point through pivot *B* to intersect the pivot *A* scale: locate the ΔP value on the nomograph and extend a line from that point through the point on the pivot *A* scale to intersect the D_o scale, giving the answer. Two examples will show the uniqueness of the capacity constants: 1) $\Delta P = 25$ psi; $W = 0.171$ lb/sec; $D_o = 0.119$ in.; 2) $\Delta P = 100$ psi; $W = 0.345$ lb/sec; $D_o = 0.119$ in.

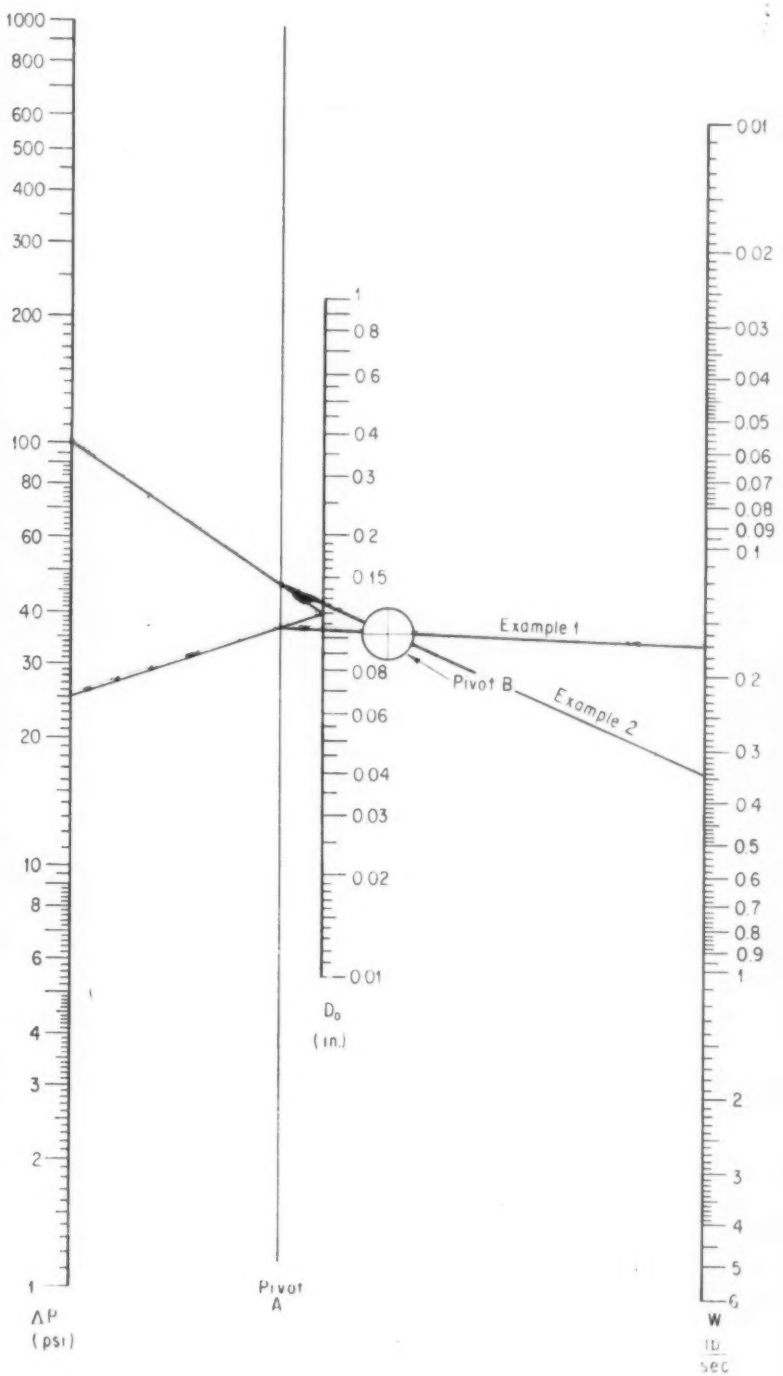


TABLE I.. Comparison of flow constants

BASIS FOR CONSTANT	COMMENTS	TYPICAL EQUATIONS
$C_v \propto Q/(P_i - P_o)^{\frac{1}{2}}$	Although based on liquid, C_v and D_o are applicable to gas. It depends on the expression used.	Q, gpm $= C_v \sqrt{P_i - P_o}$ for water
$D_o \propto Q^{\frac{1}{2}}/(P_i - P_o)^{\frac{1}{4}}$		Q, gpm $= 18.1\ D_o^2 \sqrt{(P_i - P_o)}$ for water (sharp-edged orifice)
$F \propto Q/(P_i^2 - P_o^2)^{\frac{1}{2}}$	For air at standard conditions.	Q, scfm $= F \sqrt{\frac{4}{3}} \sqrt{P_i^2 - P_o^2}$
$K \propto \frac{A^2}{Q^2}/(P_i - P_o)$	$\rho V^2/2g$ is velocity head in psi.	$\Delta P = K\left(\frac{\rho V^2}{2g}\right) = K\left(\frac{\rho Q^2}{2gA^2}\right)$

TABLE II.. Flow factor, F, for tubing (NBS equations)

For short tubes ($L \leq 10$ dia)	A = cross-section area, sq in.; d = ID, in.; f = friction factor; L = length, in.	$F = 16.5A$
For long tubes ($L > 10$ dia)		$F = 23.5A \sqrt{(d/fL)}$

method are easily made and are among the topics covered in a previous article (*PE—Oct* 26 '59).

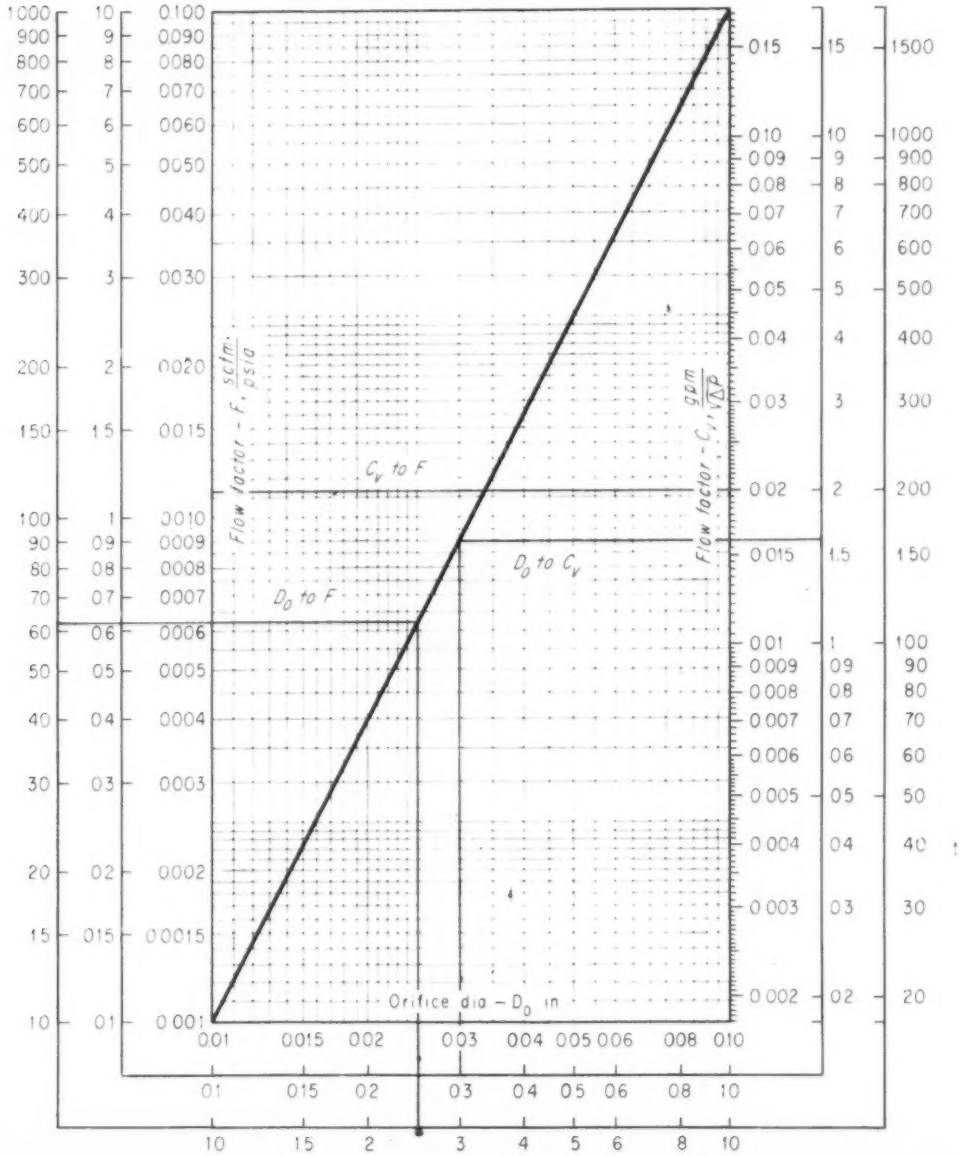
Catalog data

Actual tabulated or plotted performance is the most basic flow information in a catalog—though not often provided. Conversion to flow factor F is accomplished in three steps with the help of Fig 1. Plot flow (lb/sec of water) vs pressure drop (psi) using whatever catalog information is provided; graphically determine effective orifice diameter D_o using the nomograph; and convert D_o to F with Fig 2.

More common than plotted performance are the various flow constants used in flow-vs-pressure-drop equations. Two types are easily converted to flow factor F: they are flow coefficient C_v and effective orifice D_o. Other methods such as the K-factor technique (*PE—Apr.* 14 '58) are not mathematically similar to flow factor F and require special conversion techniques (one is to plot calculated test points and convert to flow factor F graphically). The constants are sum-

2..C_v-D_o-F conversion

Flow constants C_v, D_o and F are directly related mathematically as follows: $D_o = 0.236 \sqrt{C_v}$; $C_v = 1.77\ F$; $F = 9.9\ D_o^2$. These three examples show how to read the values directly: if $D_o = 0.03$ in., $C_v = 0.016$; if $C_v = 0.02$, $F = 0.01125$; and if $F = 62$, $D_o = 2.5$.



marized in table I. C_v, D_o and F may be converted in Fig 2.

In brief, here is how each of the flow constants works: Flow coefficient C_v by definition equals 1.0 if the component will pass 1 gpm of water with a pressure drop of 1 psi. Intermediate values of water flow, flow coefficient and pressure drop are determined with the relationship gpm $= C_v \sqrt{\Delta P}$. Compressible flow does not have the same equation, but the value for C_v obtained with water adequately defines the component flow characteristics and may be used in gas equations or it may be converted to the NBS flow factor.

Be careful when applying C_v values obtained from different sources: some companies combine C_v with other constants to develop special flow coefficients unique to their own products. However, they will usually give you standard flow coefficients on request. Or you can plot several calculated points in the recommended system of units, and convert to flow factor F starting with Fig 1.

Effective orifice D_o simply defines the diameter of a hypothetical sharp-

TABLE III.. Nomenclature

FLOW	W	weight flow, lb/sec
	Q	volume flow, cfm
	Q_A	airflow, scfm (14.7 psia, 70 F)
PRESSURE	P_U	inlet (upstream) pressure, psia or psig
	P_D	outlet (downstream) pressure, psia or psig
	P_D/P_U	pressure ratio, psia/psia
	Z	function of pressure ratio, plotted on next page
GAS CONSTANTS (see table of values)	ρ	density, lb/cu ft
	R	gas constant (53.3 for air)
	γ	ratio of specific heats, C_P/C_V
	$(\rho_G/\rho_A)_{std}$	relative density of a gas and air at standard conditions
FLOW CONSTANTS and passage dimensions	C_D	coefficient of discharge for orifice
	C_V,K, F,D_O	flow constants, described in text
	A	cross-section area
SUBSCRIPTS	U,D	upstream, downstream
	A,G	air, gas

TABLE IV.. Thermodynamic constants

	Air	H_2	N_2	O_2	He	A	CO	CO_2	NH_3	CH_4
ρ_G/ρ_A	1.00	0.0695	0.968	1.105	0.1381	1.379	0.967	1.530	0.596	0.554
R	53.36	766.6	55.16	48.29	386.2	38.69	55.19	35.12	90.74	96.40
γ	1.402	1.409	1.400	1.399	1.66	1.66	1.400	1.301	1.319	1.319

edged orifice that will pass the required flow (assumed to be water) with the given pressure drop. The basic equation is gpm $= 18.1\ D_o^2\ \sqrt{(P_U - P_D)}$ and includes a discharge coefficient of 0.61—an average value for such orifices.

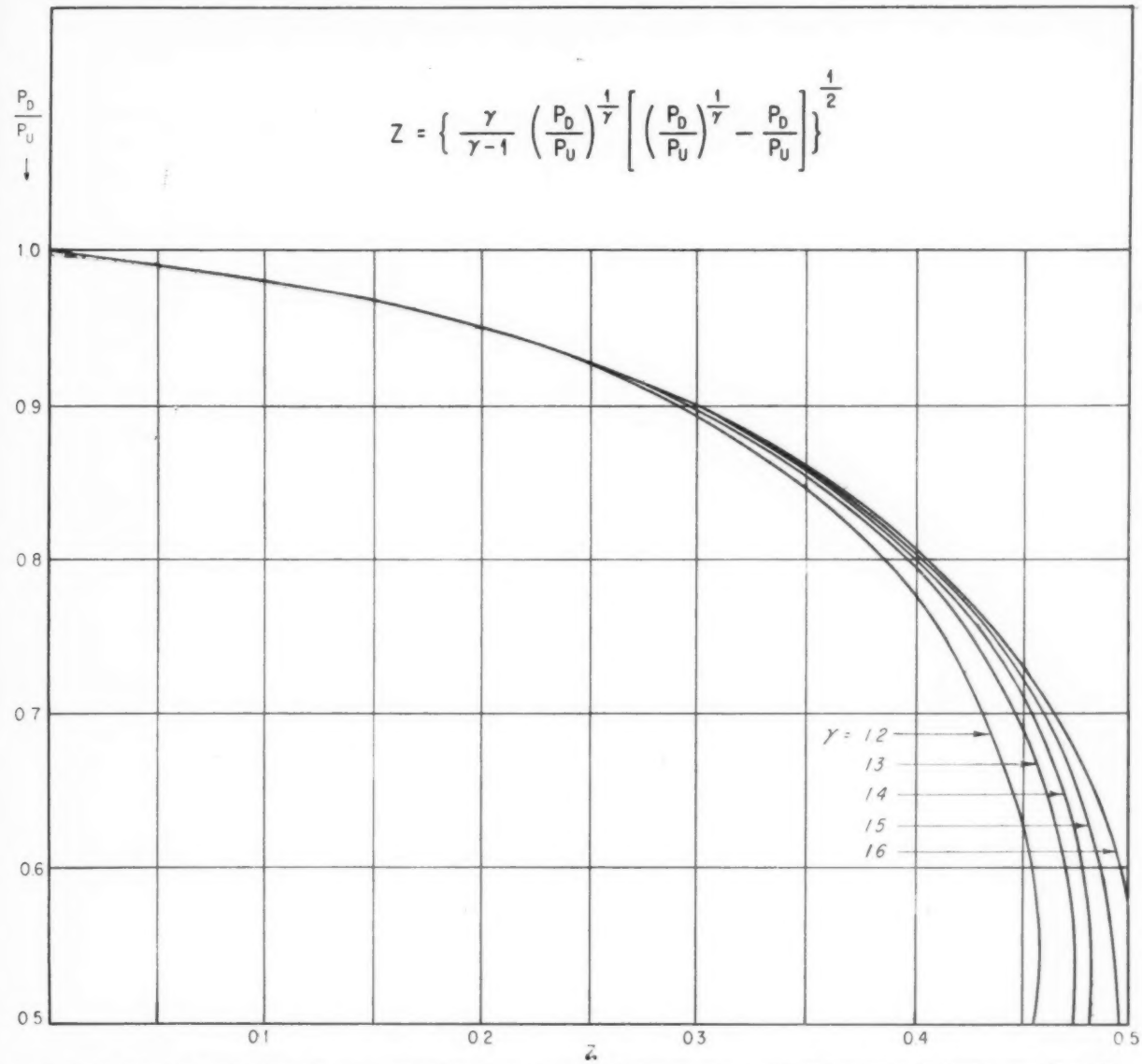
K-factor method assumes that pressure drop in piping and components is a function of the stream velocity: $\Delta P = K\rho V^2/2g$. For a given valve configuration the pressure drop will quadruple if stream velocity doubles.

Equivalent pipe length is another measure of pressure loss in a component or piping system, and it too can be converted to flow factor F. This conversion has been covered in a previous article (*PE—Apr* 14 '58). The basic relationships—dependent on friction factor—are briefly summarized in table II.

Convert airflow to scfm

Before you can insert values into the final nomograph of the series you must first convert volume flow of whatever gas you are using into volume flow of air at standard conditions (14.7 psia, 70 F). The final nomograph is based on scfm—standard cu ft/min. The values of P_U, P_D and their ratio P_D/P_U remain the same

3..Expansion factor Z



This graph is needed only when the gas has a different γ than air because Z_A/Z_G (see airflow equations below) will be unity if $\gamma_G = \gamma_A = 1.402$. Nitrogen, oxygen and hydrogen, for example, have γ's of about 1.4 and conversion to standard airflow units is simple—see Case 5 on the last page of the article for an example using nitrogen.

before and after the conversion from actual flow to scfm. Here is why.

Flow is a function of passage geometry and the thermodynamic properties of the gas. The thermodynamic expression for weight flow in lbs/sec is:

$$W = 12AC_D\rho_U \sqrt{2g \frac{\gamma}{\gamma-1} \frac{P_U}{\rho_U} \left[1 - \left(\frac{P_D}{P_U}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

If two flow passages are identical and each carries a different gas at the same pressure conditions, the ratio of flow between the two gases depends only on the thermodynamic properties. For air (subscript A) and any gas (subscript G) the ratio of weight flows is expressed as follows:

$$W_A = W_G \frac{Z_A}{Z_G} \sqrt{\frac{R_G T_G}{R_A T_A}}$$

where:

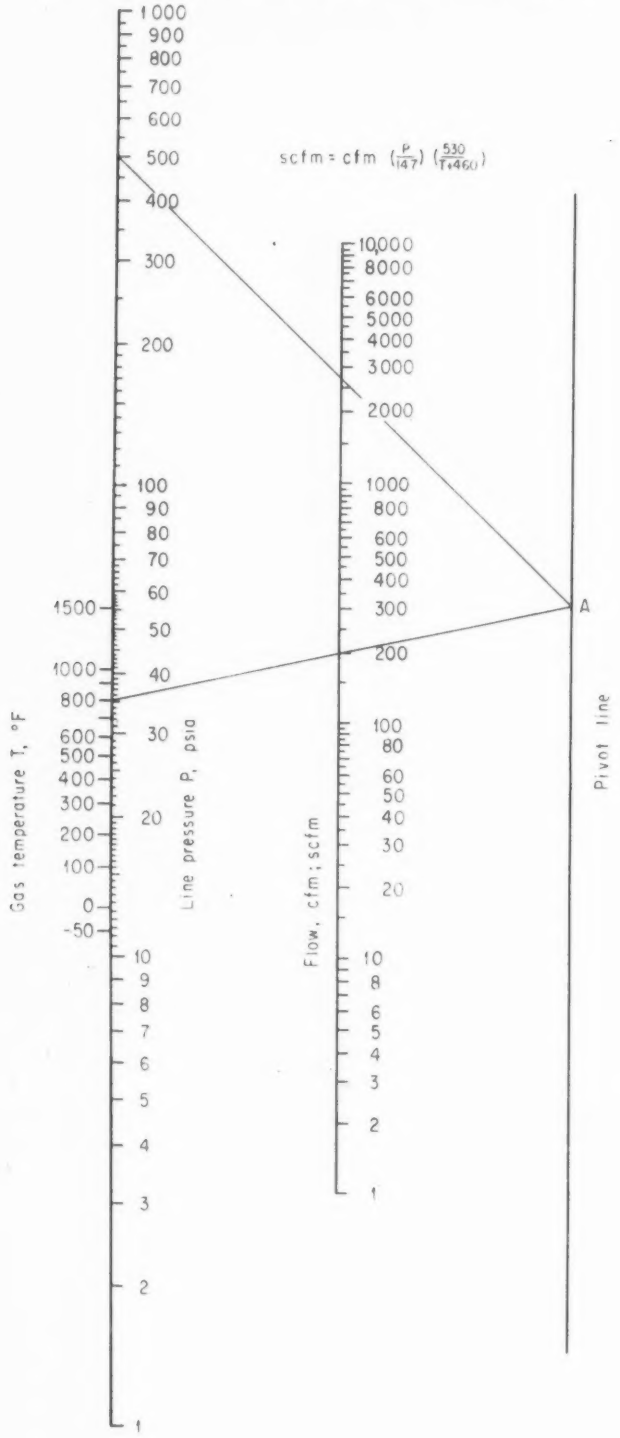
$$Z = \left\{ \frac{\gamma}{\gamma-1} \left(\frac{P_D}{P_U}\right)^{\frac{1}{\gamma}} \left[\left(\frac{P_D}{P_U}\right)^{\frac{1}{\gamma}} - \frac{P_D}{P_U} \right] \right\}^{1/2}$$

The coefficient Z combines the specific-heat constants and pressure ratio; values of Z vs P_D/P_U are plotted in Fig 3.

Weight flow must be converted to volume flow in order to use the flow nomograph, Fig 5; this is done by in-

4..Airflow in scfm

Airflow in scfm can be read directly if you know actual airflow in cfm and actual pressure and temperature. For example, convert a flow of 200 cfm at 800 F and 500 psia to scfm (standard cfm at 14.7 psia and 70 F): first locate 800 F on temperature scale and 200 on the cfm-scfm scale; draw line through both points to pivot line; from pivot line draw line connecting 500 psia on the pressure scale; and where this line intersects the cfm-scfm scale is the converted flow, 2700 scfm.



troducing gas-to-air density ratio (ρ_G/ρ_A), measured at standard conditions. The expression for airflow in scfm becomes:

$$Q_A = \frac{1}{168.1} Q_G \left(\frac{\rho_G}{\rho_A}\right)_{Std} \left(\frac{Z_A}{Z_G}\right) \sqrt{R_G T_G}$$

Solve for Q_A in the above equation and substitute its value in the flow nomograph. Constants R, γ and ρ_G/ρ_A for various gases at standard conditions are listed in Table IV. See sample problems at the end of the article for details of this computation.

When air is the fluid, the conversion from actual flow to standard flow can be made quickly with Fig 4. No need to solve the gas-to-air equation.

Solve the flow problem

The final nomograph (Fig 5) will solve any one of these three major flow problems: pressure drop when inlet pressure, flow, and flow factor are known; flow when pressures and flow factor are known; and required flow factor when flow and pressures are specified.

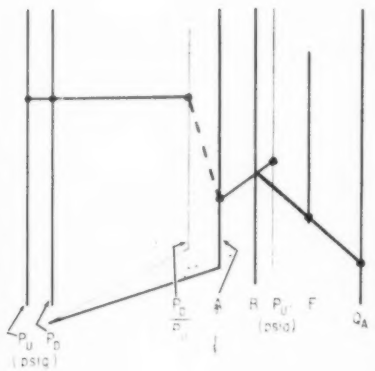
The nomograph solves the expressions:

$$Q_U/F = \sqrt{(8/5)}\sqrt{[r(1-r)(3-r)]}$$

where $r = P_D/P_U$ in absolute units; and $Q_A = F\,P_U(Q_U/F)$ which is based on the NBS definition for F. The two scales for P_U on the nomograph are necessary because the two expressions have unlike nomographic characteristics. In addition, one of the two scales is in psig and the other is psia to help avoid errors in choosing the right scale. Note that this expression for Q_U/F differs from the simpler NBS relationship given before: it is the mean between ideal isentropic expansion and the basic NBS equation which assumes high stagnation loss.

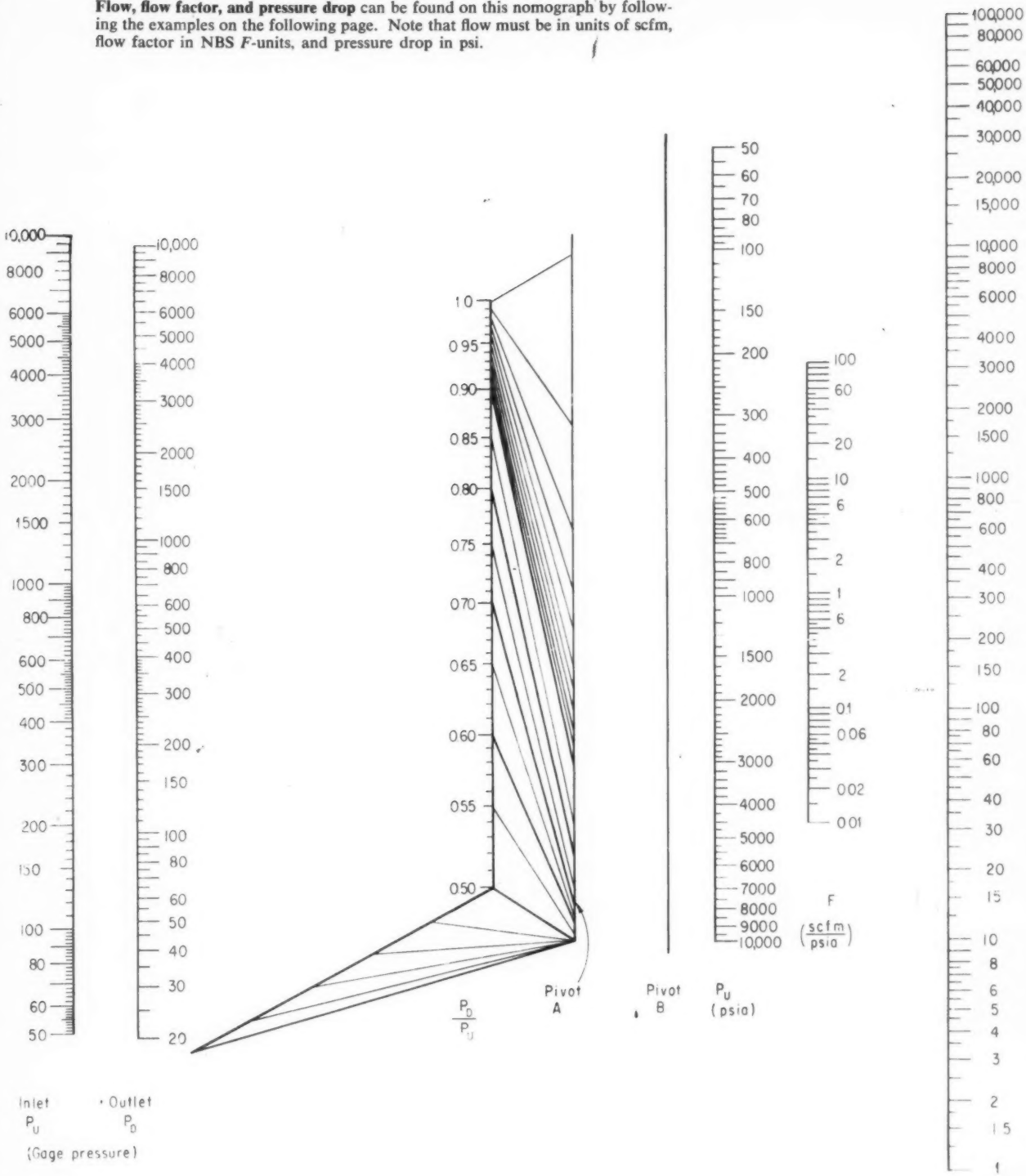
The best way to explain the nomograph is to work out examples. The

text continued, page 34

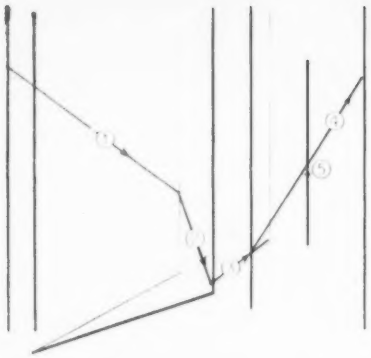


5..Flow, flow factor, pressure drop

Flow, flow factor, and pressure drop can be found on this nomograph by following the examples on the following page. Note that flow must be in units of scfm, flow factor in NBS *F*-units, and pressure drop in psi.



REDUCED-SCALE REPLICA (left) of the flow nomograph above shows how it works. The three leftmost scales (guideline in red) simply solve for pressure ratio (or for the unknown pressure if the ratio is known). Pivot line A is there to transfer the value for pressure ratio to a different logarithmic scale for the right half of the nomograph. The five right scales relate pressure ratio, inlet pressure, flow factor, and flow in standard cfm: if any three are known, the fourth can be found. See examples of the application of this nomograph to five realistic problems on next page.



CASE 1 . . . find flow factor F

Given: P_U = 4000 psig = 4014.7 psia
P_D = 2500 psig = 2514.7 psia
Q_A = 2000 scfm

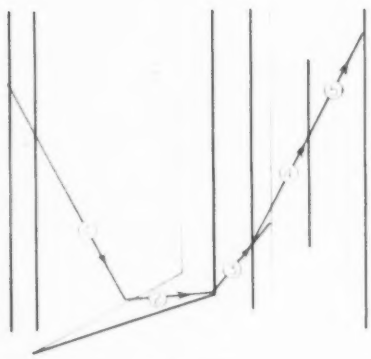
Step 1. . Connect P_U = 4000 psig and P_D = 2500 psig on the gage pressure scales and extend a line to intersect P_D/P_U scale.

Step 2. . Transfer point on P_D/P_U scale to pivot A scale by following nearest guide line.

Step 3. . Connect point on pivot A scale to absolute inlet pressure (4014.7 psia) on P_U (psia) scale with a straight line.

Step 4. . From intersection on pivot B scale, draw line to connect flow (2000 scfm) on Q_A scale.

Step 5. . Intersection of line at 0.5 on F scale is then the required flow factor to satisfy the given conditions.



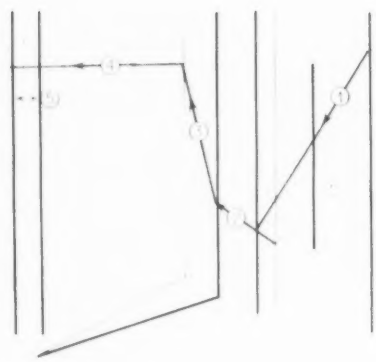
CASE 2 . . . find flow Q_A

Given: P_U = 3000 psig = 3014.7 psia
P_D = 1000 psig = 1014.7 psia
F = 2.0 scfm/psia

Steps 1, 2, and 3: identical to those of Case I solution.

Step 4. . From the intersection on pivot B scale, draw a line to connect flow factor (2.0) on the F scale.

Step 5. . Extend line to cross Q_A scale at 6250 scfm.



CASE 3 . . . find pressure drop $P_U - P_D$

Given: P_U = 4000 psig = 4014.7 psia
Q = 4000 scfm
F = 2.0 scfm/psia

Step 1. . Connect 4000 on Q_A scale and 2.0 on the F scale. Extend line to intersect pivot B scale.

Step 2. Connect point on pivot B scale to 4014.7 psia on P_U (psia) scale.

Step 3. Transfer point to P_D/P_U scale in a manner similar to that outlined in **Step 2**. . Case I solution,

Step 4. . Connect this point on the P_D/P_U scale to 4000 psig on the P_U (psig) scale.

Step 5. . The pressure drop is the difference $P_U - P_D$ or 300 psi.

first three are straight forward ones for airflow, and cover each of the three major flow problems described in the first paragraph of this section. The last two problems are special ones: for tubing, and a nitrogen valve.

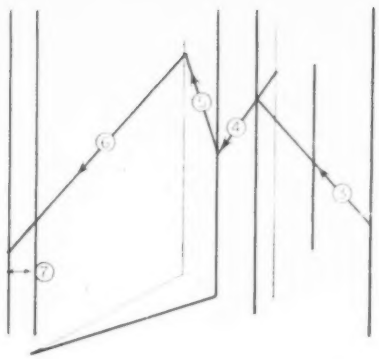
For **reprint** of above article, just check 642 on one of the Reader Service cards found in this issue.

EDITOR'S NOTE: Other methods of determining flow, flow constant, and pressure drop for gases and liquids have been covered in these previous PE articles:

Pressure Drops in Pneumatic Components and Systems, 1955 Annual Handbook (Mid-Oct '54) p J-2—This is the original report of the NBS flow-factor method, covering the theory and corroborating test data (briefly summarized in the article in this current issue).

Pressure Losses in Pneumatic Systems, Oct 26 '59, p 60—The NBS flow factor is manipulated to permit flow calculations for components and piping in series and parallel, with a worked-out example of a piping system with three branches. Given are

CASE 4 . . Find pressure drop in tubing



Given: L = 10 ft (120 in.)
d = 0.391 in. ($\frac{1}{2}$ in. nominal).
$A = \pi d^2/4$ = 0.12 sq in.
f = 0 02 (typical for AN-type tubing)
P_U = 200 psig (214.7 psia)
Q = 5.0 cfm at 120 F and 200 psig

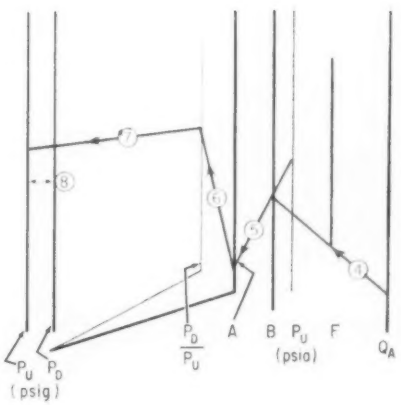
Step 1..Calculate equivalent flow factor F from table II.

$F = 23.5A\sqrt{(d/fL)} = 23.5 \times 0.12\sqrt{[0.391/(0.02 \times 120)]} = 1.14$ scfm psia

Step 2..Solve for scfm with fig 4. Q_A = 70.0 scfm.

Step 3..On flow nomograph (fig 5) connect 70 scfm to 1.14 on F scale to intersect pivot B scale. Then join 214.7 psia on P_U absolute scale with point on pivot B scale to intersect pivot A scale. Transfer this point up to P_D/P_U scale and connect to P_U gage scale. Read P_D scale intersection at 195 psig. Pressure drop is 200 − 195 = 5 psi.

CASE 5 . . nitrogen, special flow constant



Given: C_V = 0.02
T_G = 500 F = 960 R
P_U = 1000 psig = 1014.7 psia
W_G = 0.01 lb/sec nitrogen flow rate

Step 1..From the C_V-D_O-F conversion chart, a valve with a C_V of 0.02 has an equivalent flow factor of 0.01125 scfm/psia.

Step 2..Nitrogen weight flow must be converted into air flow (weight units) at standard temperature (530 R) by using the formula:

$$W_A = W_G \frac{Z_A}{Z_G}\sqrt{\frac{R_G T_G}{R_A T_A}}$$

The ratio Z_A/Z_G is practically unity throughout the whole pressure range because γ_G is nearly equal to γ_A. This is fortunate, because for gases having unlike γ's the problem becomes complex and unless more information is known a solution must be found by trial and error. You would use the airflow chart and work from sonic velocity (maximum pressure drop) until a minimum pressure drop was found.

For nitrogen, it's easy: the conversion formula reduces to:

$$W_A = W_G\sqrt{\frac{R_G T_G}{R_A T_A}}$$

where

R_G = 55.16 for nitrogen
R_A = 53.36 for air
T_A = 530 R for air at standard temperature

then

$$W_A = 0.010\sqrt{\frac{55.16 \times 960.0}{53.36 \times 530.0}}$$

W_A = 0.01369 lb/sec equivalent air flow

Step 3..Convert airflow W into standard air volume flow (scfm units) with the equation $Q_A = 800W_A$ where the constant 800 is $60/\rho_o$ and ρ_o is air density at standard conditions. $Q_A = 800 \times 0.01369$ = 10.95 scfm (airflo

Step 4..Follow Case III to solve the airflow problem. ΔP = 240 psi.

graphs of flow factor F and equivalent pipelength for fittings.

Pressure Drops in Air Valves, Apr 14 '58, p 74—The K-factor method where $\Delta P = K \rho V^2/2g$ is described in detail, with tables and graphs of K-factors for valves and fittings.

Flow Through an Orifice, Oct 2 '61, p 91—Author Lapera in this previous article gives a shortcut method for estimating liquid flow based on equivalent orifices. The value D_o obtained is also applicable to airflow problems.

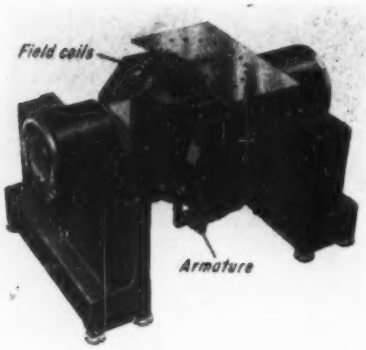
Many liquid flow problems are solved for you in this previous group of PE articles:

Pressure-drop Calculations, June '54, p 197—Gives a method for calculating flow and pressure loss in hydraulic components.

Pressure Losses in Hydraulic Branch-off Fittings, July 20 '59, p 60—Results are interpreted for a series of tests on elbows, tees, and special takeoff connections.

Pressure Losses in Flexible Metal Tubing, Apr '59, p 223—Tabulates friction-factor coefficients for concentric and helical corrugated tubing.

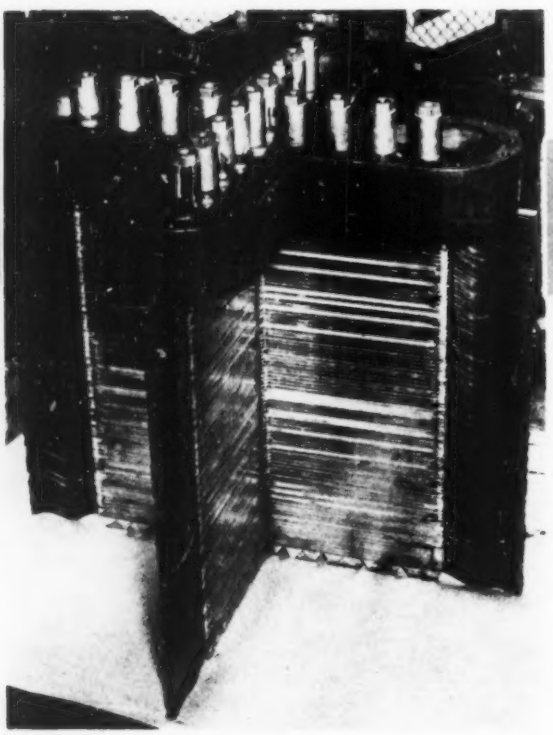
—F D Yeaple

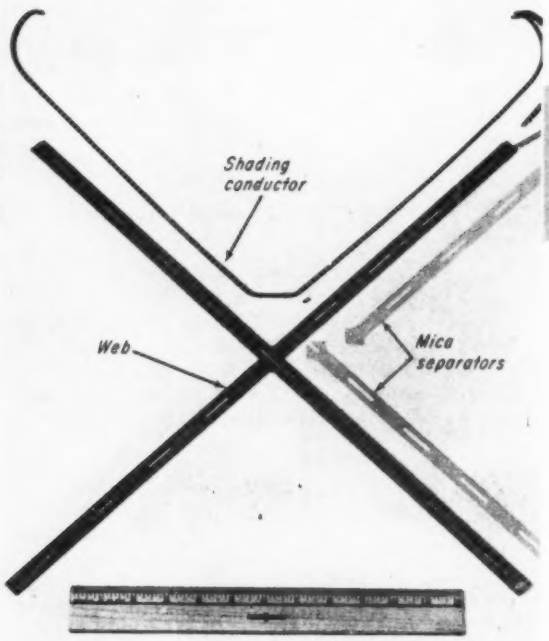


Shaker armature

Electrical and mechanical elements are joined to produce a light armature with high natural frequency.

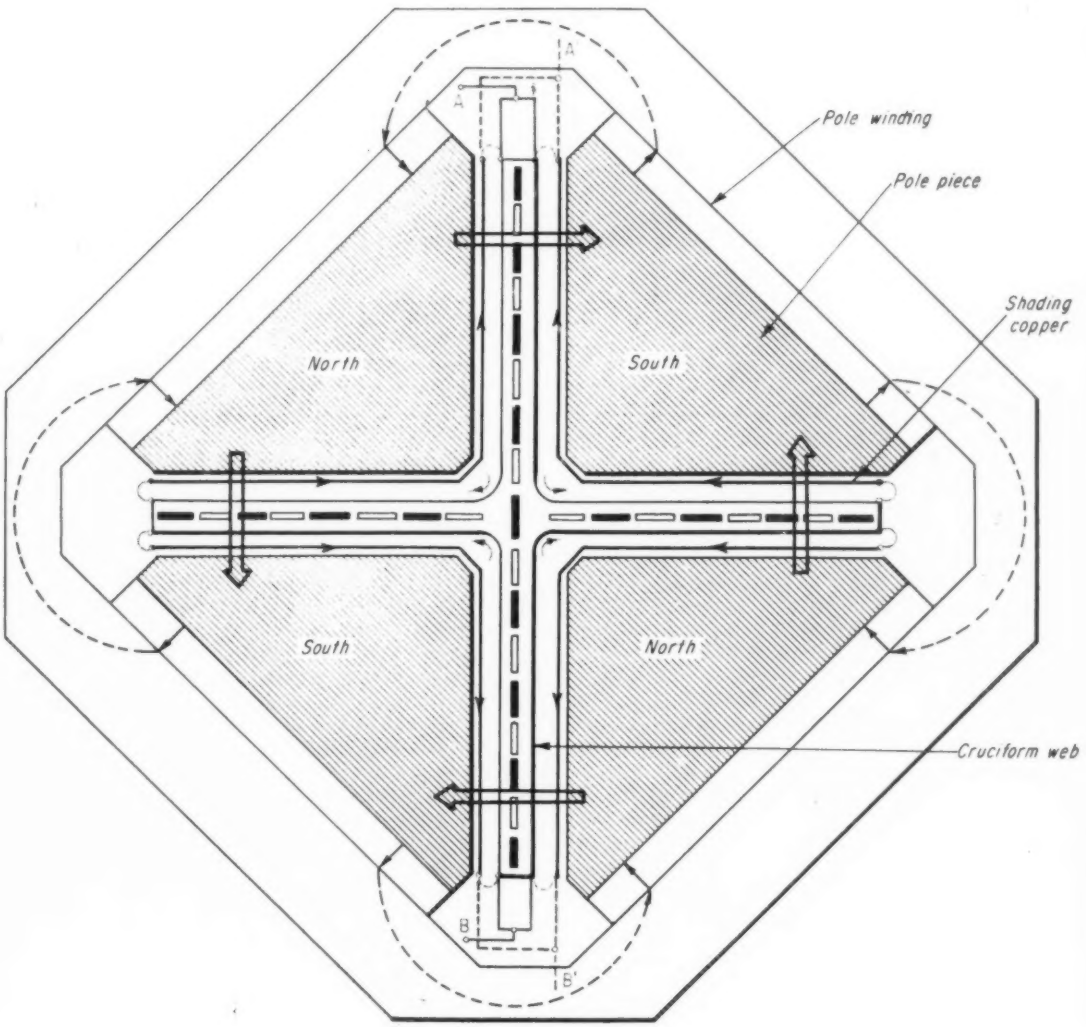
CROSSED armature is an improvement on the usual shaker design which incorporates a ring-type voice coil. Armature weight, for the 22,000-lb unit is less than 115 lb. This light weight results in a bare table acceleration of 200 *g*. Axial resonant frequency is over 2000 cps and the shaker can be operated to 3000 cps. Measured stray magnetic field at the table is 3 to 5 gauss compared to 100 to 150 gauss for conventional vibrators. Mechanical wear is minimized by a continuous oil film also acting as coolant for the armature. The L-200 shaker is produced by Ling Electronics Div, Ling-Altec Electronics Inc, Anaheim California.





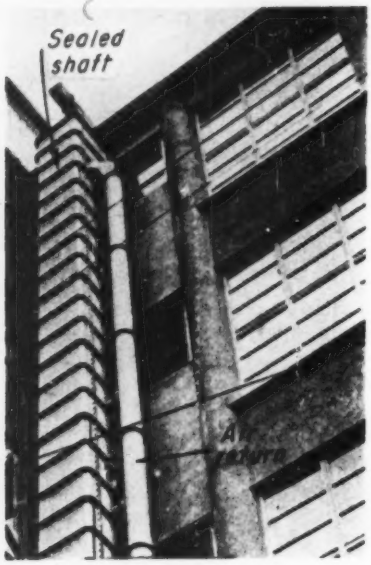
CRUCIFORM ARMATURE webs are slotted along each arm and have a teflon-covered flexible lead soldered to the arm and its corresponding shading conductor. Insulated steel straps are passed through alternate web slots and separator slots and preloaded to 5000 lb per strap. The 17 straps produce a total compressive force of 85,000 lb on the web layers. Upper ends of the straps terminate in bosses which protrude through the table top and to which the test specimen is attached. The assembled armature is suspended from a rubber seal acting in shear for axial movement and in compression for lateral movement. This produces a suspension which is stiff for lateral but compliant for axial movement.

takes form of a cross



STATOR POLE pieces are wound to establish the indicated magnetic flux pattern. Current from the amplifier enters the top lamination of the armature at two points 180° apart (A and B). Current flows in to the center and then splits to go out along left and right legs of the web. Return is through the shading wires back to points A′ and B′.

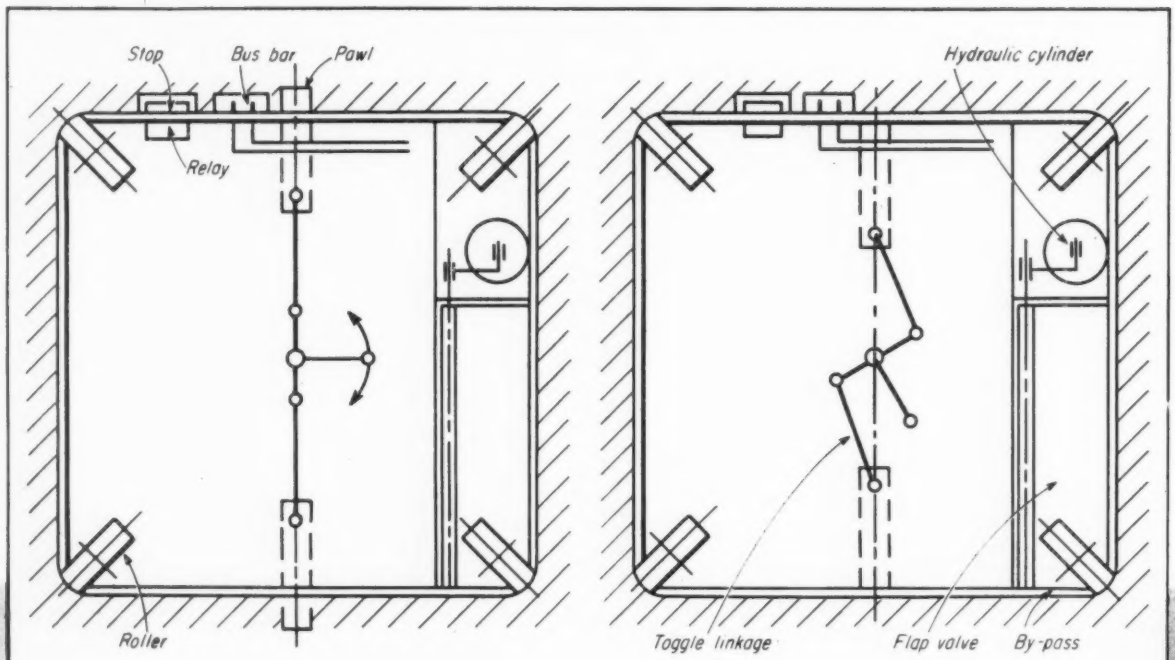
As with voice-coil armatures, force multiplication is achieved by passing the same current repeatedly through the flux field. Since each cruciform web is insulated from the rest, current can be conducted in the same pattern from lamination to limination, down the stack.



Air lifts freight

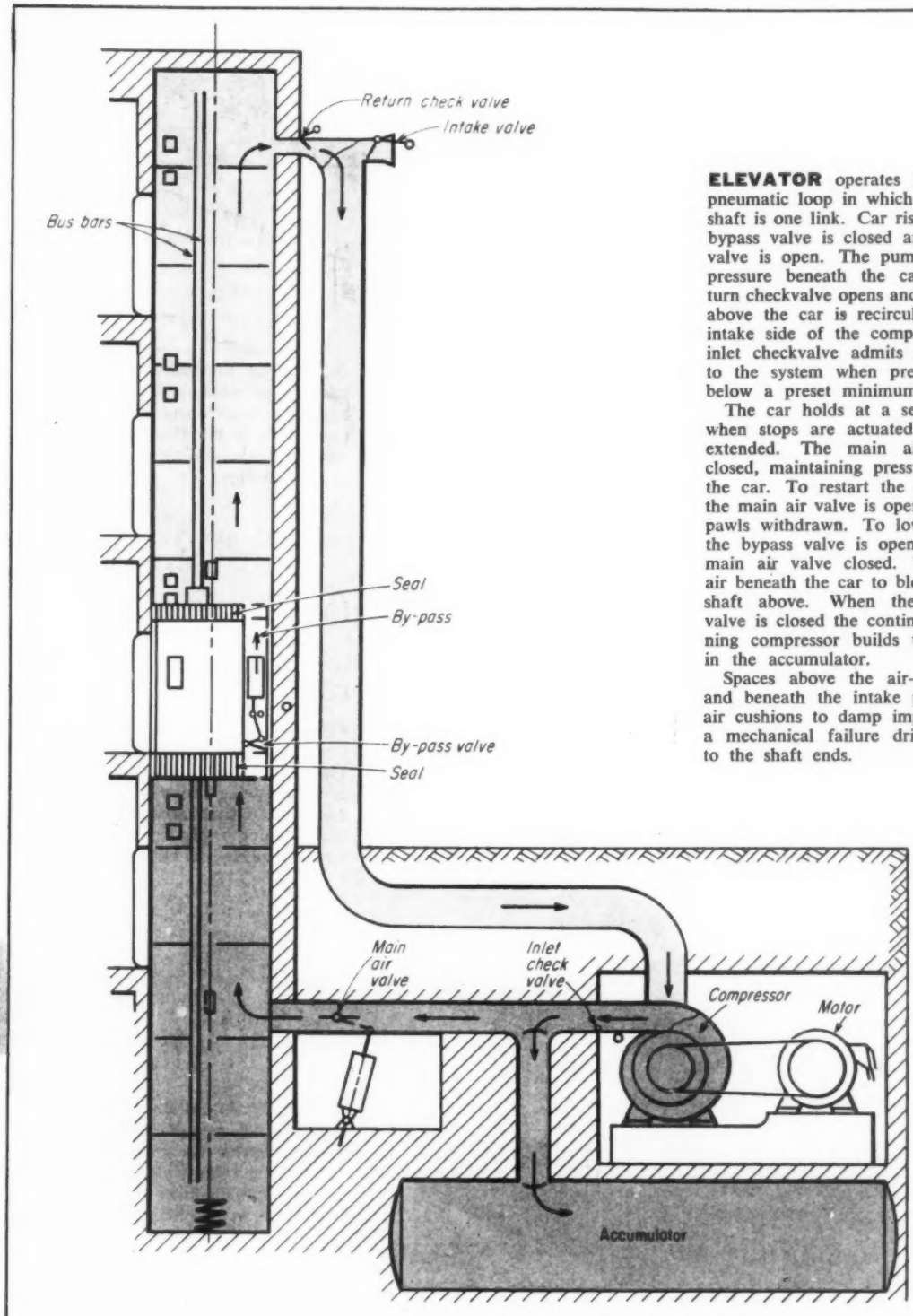
Cable-less car rides on a cushion of air. Seals retain supporting pressure in airtight shaft.

FREE PISTON principle is applied in a Czech elevator which has compressed air beneath and a slight vacuum above to move freight car. Pressure of only 12 to 16 in. H_2O is adequate in an airtight sheet steel shaft bolted to outside of 6-story building. Interior installations for passenger service are next. Cable-less design was developed at ZPS Precision Engineering Plant, Gottwaldow, Moravia, Czechoslovakia.



TIGHT-CORNER rollers hold square car in shaft. Air seals at top and bottom prevent blowby. Bypass passage and flap valve at the rear release air trapped beneath the car. The bypass flap valve is operated by an electrically controlled hydraulic cylinder. Speed of descent is controlled by throttling air through the adjustable flap valve. To position the car at a floor, electromagnetically operated stops first engage recesses in the shaft wall. They signal the appropriate valves to stop the car. Control signals are transmitted through brushes riding on electrical bus bars attached to the shaft wall. When stopped, the car is held in position by locking pawls operated by a toggle. To restart, locking pawls are withdrawn, air valve signaled to admit air.

in free-piston elevator



ELEVATOR operates in a closed pneumatic loop in which the airtight shaft is one link. Car rises when the bypass valve is closed and main air valve is open. The pump maintains pressure beneath the car. The return checkvalve opens and air trapped above the car is recirculated to the intake side of the compressor. The inlet checkvalve admits makeup air to the system when pressure drops below a preset minimum.

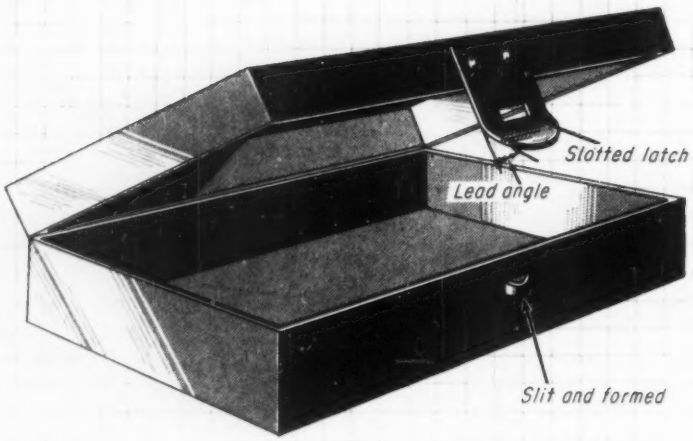
The car holds at a selected floor when stops are actuated and pawls extended. The main air valve is closed, maintaining pressure beneath the car. To restart the car upward the main air valve is opened and the pawls withdrawn. To lower the car the bypass valve is opened and the main air valve closed. This allows air beneath the car to bleed into the shaft above. When the main air valve is closed the continuously running compressor builds up pressure in the accumulator.

Spaces above the air-return port and beneath the intake port act as air cushions to damp impact should a mechanical failure drive the car to the shaft ends.

Low-cost latches give

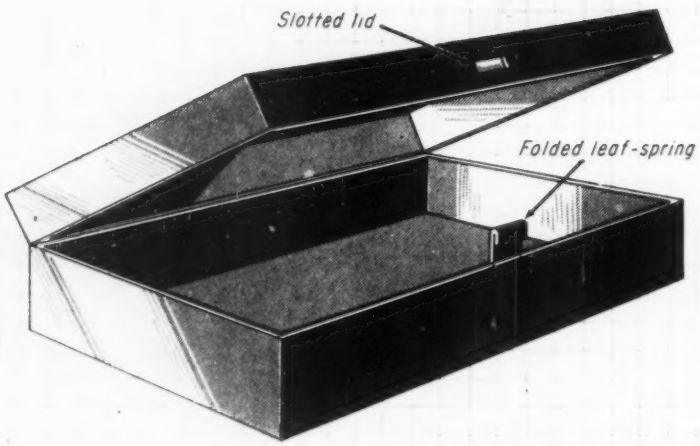
These latches cut costs where appearance is a secondary consideration.

L KASPER, design consultant, Phila



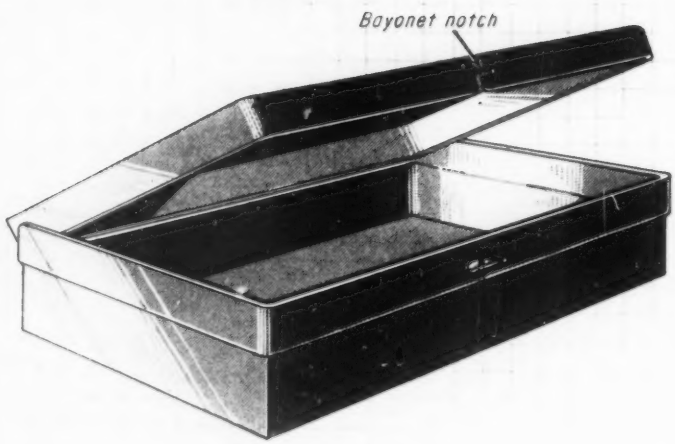
1

SLIT AND FORMED box side depends upon spring action of box metal and latch plate for engagement in latch-plate hole. A box that is too stiff will require a relatively flexible latch plate for ease of operation.



2

FOLDED LEAF-SPRING end is another positive, spring-action latch. Here, however, the leaf spring itself provides spring action — box can be as heavy as desired without interfering with opening or closing. Careful alignment of spring and notch is necessary.



3

BAYONET ACTION of formed-wire spring in lid is again automatic upon closing. Spring must be manipulated for opening unless a lead is deliberately designed into the lid notch so that opening force can overcome holding-force.

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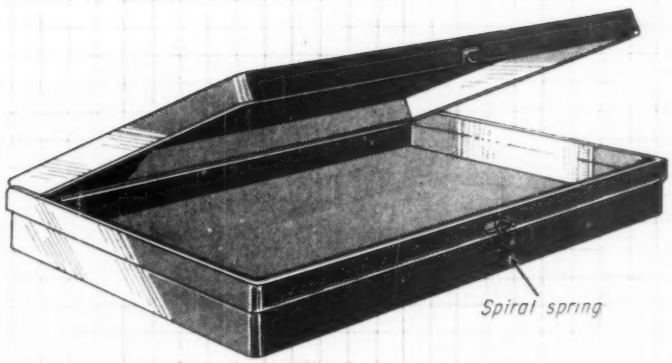
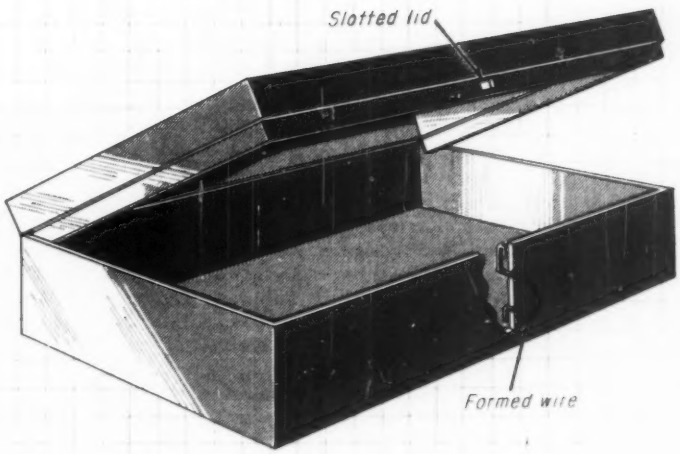
4

SPIRAL SPRING holds the lid in a manner similar to the previous latch arrangement. Spring action comes from tension windup rather than cantilever and so design is suitable for boxes where a long latch spring is not possible.



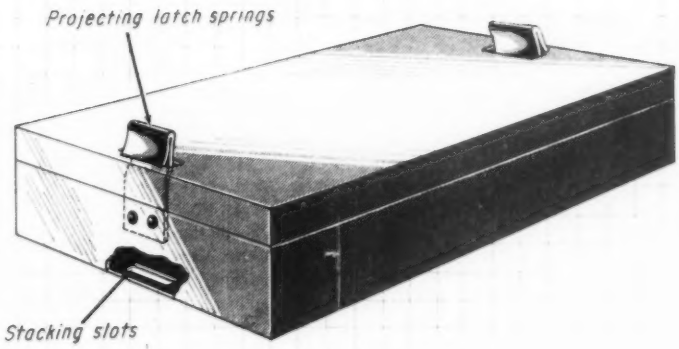
5

FINGER RING is here provided by forming the spring to do double duty — it not only performs as the latch spring but provides finger hold for withdrawing the box from a narrow shelf or desk drawer. Disadvantage is that protruding spring takes extra space.



6

LATCH SPRINGS projecting through the box top provide for stacking by engaging a slot in the bottom of the box above. Several boxes can thus be carried without risk of sliding. The lid can be hinged or completely removable.



To avoid vibration

Try this new cam profile

It is a new family of curves tailored to operate below the natural frequency of the follower system and thus avoid resonance.

A S GUTMAN, engineering specialist, Sylvania Electric Products Inc, Waltham, Mass

HERE'S a way to design cam profiles which will avoid setting up vibrations in the follower system. A new family of curves is suggested, ranging between the limits of two popular but, as will be shown, undesirable cam curves—the parabolic and the cycloidal profiles. The new curves offer customized design—you select a curve from this family which has an exciting or "forcing" frequency, just below that of the natural frequency of the follower system.

Cams are frequently the limiting factor in boosting the operating speed of a machine. The function of the cam usually is quite simple—to move a spring-loaded follower a distance x (Fig 1) during an elapsed time, t. There are many cam profiles that can do the job. A poorly selected profile, however, produces vibration and high dynamic loads at high speeds which cause havoc to the machine's functions and to its components.

The classical method of designing cams—still described in many modern textbooks—is to design the cam profile to provide minimum acceleration to the follower. The parabolic profile does result in minimum acceleration, but has a high "harmonic content", in other words, it is very likely to induce vibrations. Many designers avoid this curve, although its negative characteristics have not been clearly established. In its place they use the cycloidal profile—a fair choice at best because of its high-acceleration characteristics.

By employing Fourier methods, the analysis presented here has established these important facts:

1—The cycloidal profile is least likely to excite vibrations in the follower—but at the expense of dynamic loads. It causes 57% higher acceleration in the follower than with a parabolic profile.

2—The parabolic profile has the lowest possible value of acceleration for any curve—but it has infinitely high harmonic content (at all frequencies) and, therefore, will excite vibrations in any follower system, regardless of its natural frequency.

3—There is a mathematical connection between the cycloidal and parabolic curves. The Fourier equation for a parabolic curve has infinite number of terms. Drop off all terms but the first and you obtain the equation for the cycloidal curve. The more terms permitted in the equation, the higher the number of forcing frequencies.

4—A new profile—and its design equations—is developed which has a harmonic content to only three times the frequency of the cycloidal and an acceleration only 29% higher than that of the parabolic cam. By retaining more and more terms in the Fourier equation, a series of cam profiles are obtained, each with a slightly higher frequency of harmonic content, but lower acceleration characteristics, than its predecessor.

The analysis is based on a cam with linear motion and a follower with a point-like knife edge, as shown in Fig 1. However, once this basic cam is designed, its design parameters can easily be applied to circular cams by transposing from linear to polar coordinates (as will be shown). Followers are not usually point-like. Practical profiles can be obtained by first plotting the motion of the point-like follower and then the motion of the actual follower over the prescribed motion-time path. The envelope of the actual follower motion will then be the correct profile.

The analysis is here presented in nondimensional terms; that is, cams discussed are intended to move a follower a unit displacement in a unit period of time. The time scale, t, is equivalent to a cam moving in a straight line path and displacing a follower in the perpendicular direction, x, with the following boundary conditions:

When time $t = 0$, displacement $x = 0$, and velocity $dx/dt = 0$

When time $t = 1$, displacement $x = 1$, and velocity $dx/dt = 0$

The parabolic profile

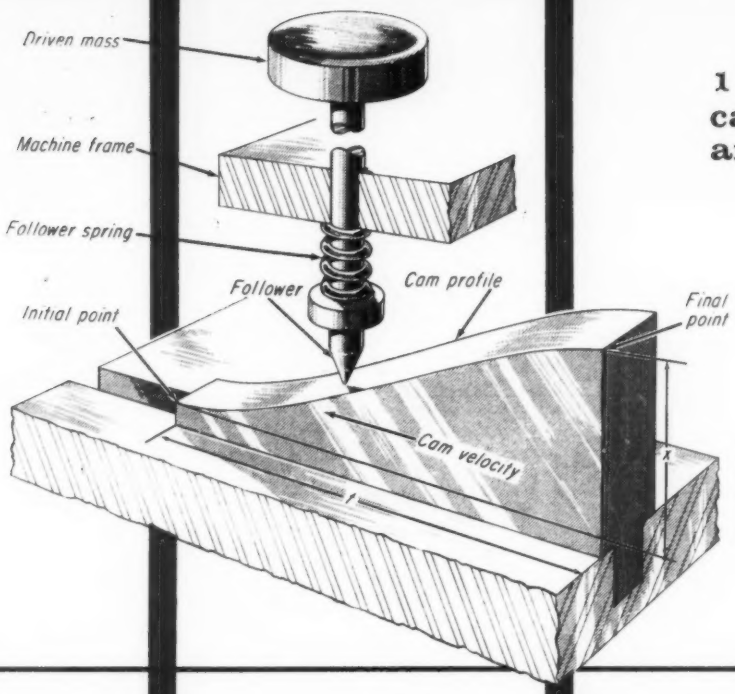
If all parts were perfectly rigid and if there were zero backlash, the two-region parabolic profile, Fig 2, would induce minimum acceleration of the follower because the accelerations in each region are constant, and are therefore minimal.

There is a skew symmetry of the profile with the center at the point:

$$t = \tfrac{1}{2}, \qquad x = \tfrac{1}{2}$$

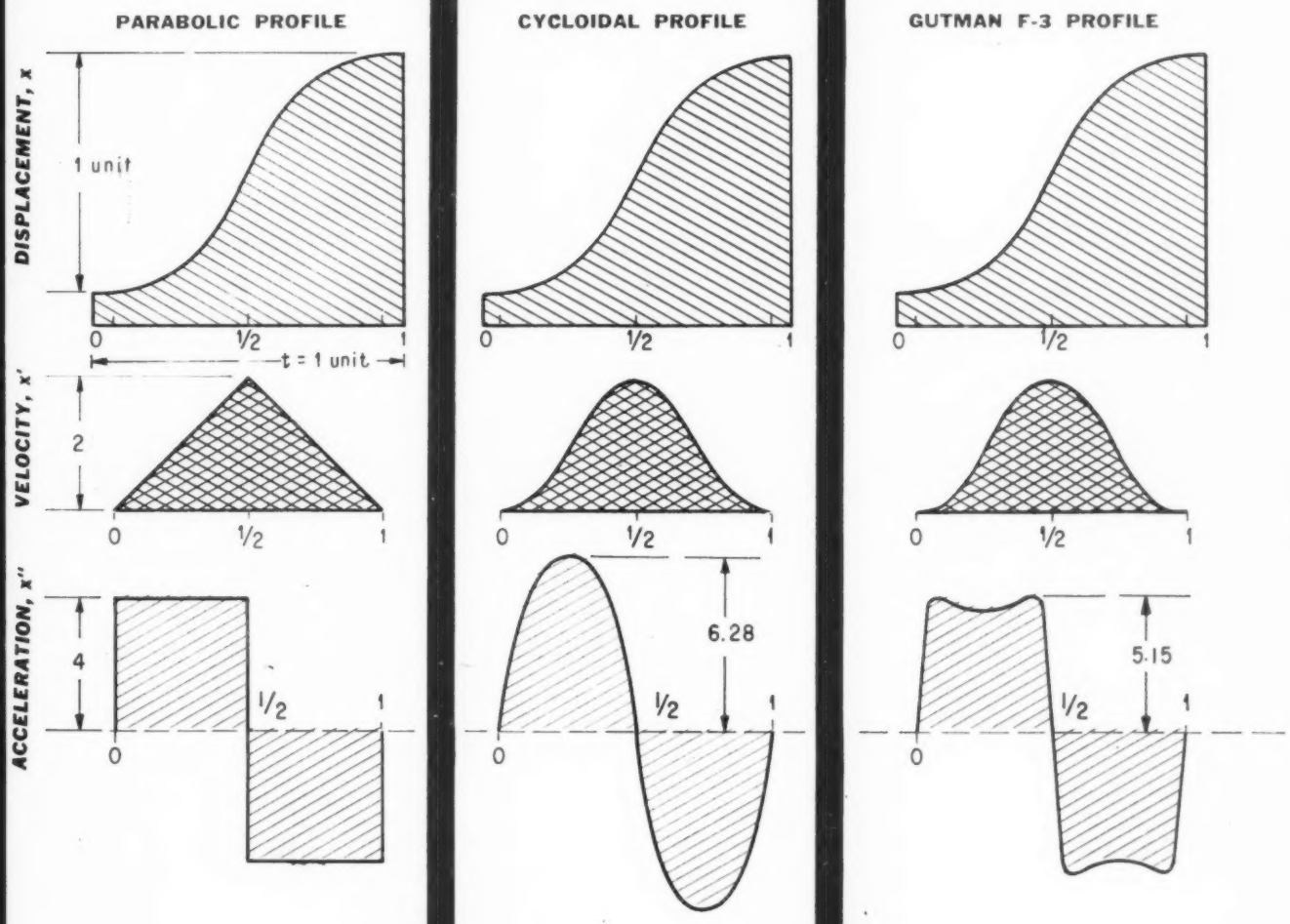
Therefore it is sufficient to define the profile equation from $t = 0$ to $t = \frac{1}{2}$, obtaining the profile from $t = \frac{1}{2}$ to $t = 1$ by symmetry. To obtain minimum acceleration, the

text continued, page 44

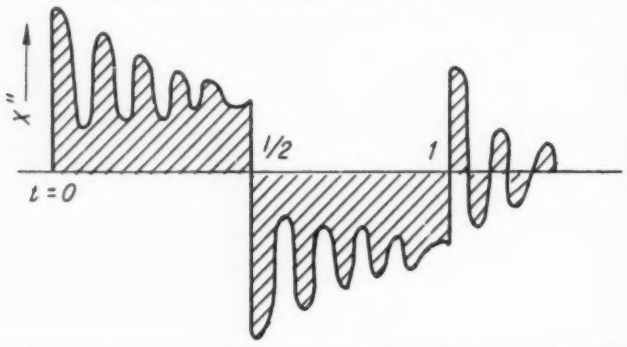


1 . . Linearized cam profile and follower system

2 . . Characteristics of three cam profiles



3 . . Effects of forcing frequency



4 . . Harmonic content of F-3 cam

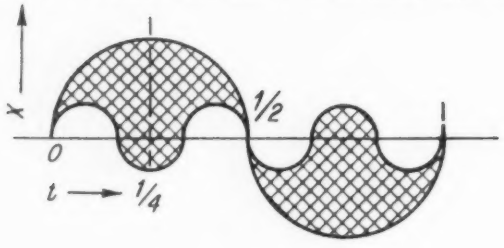


TABLE I . .

PROFILE	
DISPLACEMENT	Parabolic
	Cycloidal
	Gutman F-3
VELOCITY	Parabolic
	Cycloidal
	Gutman F-3
ACCELERATION	Parabolic
	Cycloidal
	Gutman F-3

acceleration must be constant. Then, by a series of integrations:

$$x'' = C_1$$
$$x' = C_1 t + C_2$$
$$x = \tfrac{1}{2}C_1 t^2 + C_2 t + C_3$$

where $x' = dx/dt$ (velocity), and $x'' = d^2x/dt^2$ (acceleration). From the boundary condition when $t = 0$, x and $x' = 0$, constants $C_2 = 0$, and $C_3 = 0$. Thus

$$x = \tfrac{1}{2}C_1 t^2$$

From the boundary condition $t = \frac{1}{2}$ when $x = \frac{1}{2}$, constant $C_1 = 4$. Thus in nondimensional units:

$$\begin{aligned} &\text{Displacement:} && x = 2t^2 \\ &\text{Velocity:} && x' = 4t \\ &\text{Acceleration:} && x'' = 4 \end{aligned} \qquad (1)$$

The cycloidal profile

This curve is generated from a cycloid which is the locus of a point on a circle rolling on a straight line. The equations of the cycloidal profile are:

$$\begin{aligned} &\text{Displacement:} && x = t - \frac{1}{2\pi}\sin(2\pi t) \\ &\text{Velocity:} && x' = 1 - \cos(2\pi t) \\ &\text{Acceleration:} && x'' = 2\pi \sin(2\pi t) \end{aligned} \qquad (2)$$

The maximum acceleration of this cam occurs at $t = \frac{1}{4}$, and is (from the acceleration equation of Eq 2):

$$x_{max}'' = 2\pi = 6.28$$

This is 57% higher acceleration (6.28/4 = 1.57) than with a parabolic profile.

Natural frequency of the follower

Why is the cycloidal profile, in spite of its higher acceleration, superior to the parabolic profile in high-speed applications? There must be another criterion more important than acceleration present in profile design. This criterion is obtained by analyzing the vibrations in the follower system. To avoid backlash, the follower system is spring loaded. The natural frequency of the system is determined by its mass M and spring constant K:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{M}} \qquad (3)$$

The forcing frequency of a cycloidal profile, in nondimensional terms, is $f = 1$ cycle per rise-time-period. Hence, with a cycloidal cam, vibrations can be avoided if $f_n > f$—an easy requirement to meet. Practical experience shows that f_n should exceed f by a factor of two.

Harmonic analysis of parabolic cam

To determine what the natural frequency of the follower on the parabolic profile should be, we must first perform a

Comparative values of three cams

EQUATION	FORCING FREQUENCY, f	VALUES FOR TIME, t						PERCENT OF PARABOLIC
		0	¼	½	½	¾	1	
$x = 2t^2$	∞	0	0.125	0.5	0.5	.785	1	100
$x = t - \frac{1}{2\pi} \sin(2\pi t)$	1	0	0.09	0.5	0.5	.91	1	100
$x = t - \frac{15}{32\pi} \sin(2\pi t) - \frac{1}{96\pi} \sin(6\pi t)$	3	0	0.11	0.5	0.5	.89	1	100
$x' = 4t$	∞	0	1	2	2	1	0	100
$x' = 1 - \cos(2\pi t)$	1	0	1	2	2	1	0	100
$x' = 1 - \frac{15}{16} \cos(2\pi t) - \frac{1}{16} \cos(6\pi t)$	3	0	1	2	2	1	0	100
$x'' = 4$	∞	4	4	4	−4	−4	−4	100
$x'' = 2\pi \sin(2\pi t)$	1	0	6.3	0	0	−6.3	0	157
$x'' = \frac{15}{8} \pi \sin(2\pi t) + \frac{3}{8} \pi \sin(6\pi t)$	3	0	5.15	0	0	−5.15	0	129

harmonic analysis of this profile. Employing Fourier analysis methods, the displacement x of the parabolic cam profile can be expressed as an infinite series:

$$x = t - \frac{4}{\pi^2}\left[\sin(2\pi t) + \frac{1}{3^2}\sin(6\pi t) + \frac{1}{5^2}\sin(10\pi t) + \cdots\right] \quad (4)$$

If the series is extended to infinity, this expression approaches the value $x = 2t^2$, and is thus equivalent to the equation for displacement of a parabolic curve, Eq (1).

Differentiating Eq (4) with respect to t

$$x' = 1 - \frac{8}{\pi^2}\left[\cos(2\pi t) + \frac{1}{3^2}\cos(6\pi t) + \frac{1}{5^2}\cos(10\pi t) + \cdots\right]$$

This expression, when extended to infinity, is equivalent to

$$x' = 4t$$

Differentiating again gives:

$$x'' = \frac{16}{\pi}\left[\sin(2\pi t) + \frac{1}{3}\sin(6\pi t) + \frac{1}{5}\sin(10\pi t) + \cdots\right]$$

and when extended to infinity,

$$x'' = 4$$

The same frequency components appear in each of the above expressions. For a parabolic profile, this series must be extended to infinity, giving the last term in the series an infinite frequency. It is thus impossible to design a follower system for a parabolic profile such that no vibrations are excited in the system. The effect of these vibrations is shown in Fig 3. Follower accelerations can exceed the theoretical acceleration ($x'' = 4$) of the parabolic profile by a large amount.

Harmonic analysis of cycloidal cam

What happens when all the sine terms—except the first—are dropped out of the Fourier equation for a parabolic profile? All forcing frequencies except the lowest will be omitted—and you will have derived the equation for the cycloidal profile. Here's how this is done: The coefficients of the remaining terms are determined from the boundary conditions:

for $t = 0$: $x = 0$, $x' = 0$, $x'' = 0$
for $t = \frac{1}{2}$: $x = \frac{1}{2}$, $x'' = 0$

The profile is

$$\begin{aligned} x &= C_1 t - C_2 \sin(2\pi t) \\ x' &= C_1 - 2\pi C_2 \cos(2\pi t) \\ x'' &= 4\pi^2 C_2 \sin(2\pi t) \end{aligned} \quad (5)$$

From the boundary conditions, $t = 0$ when $x' = 0$:

$$0 = C_1 - 2\pi C_2$$

and from $t = \frac{1}{2}$ when $x = \frac{1}{2}$

$$\tfrac{1}{2} = \tfrac{1}{2} C_1$$

Therefore $C_1 = 1$, $C_2 = 1/(2\pi)$, and the cycloidal pro-

file equations for displacement, velocity and acceleration:

$$x = t - \frac{1}{2\pi}\sin(2\pi t)$$
$$x' = 1 - \cos(2\pi t)$$
$$x'' = 2\pi \sin(2\pi t)$$

These equations are identical to Eq (2).

The new cam profiles

By retaining more terms in the Fourier equation, Eq (4), cam profiles are derived which combine the advantages of the parabolic (minimum acceleration) and the cycloidal (minimum forcing frequency) profiles. As an example, a cam profile is derived with a forcing frequency of $f = 3$ cycles per rise-time-period (the cycloidal has $f = 1$). This new cam profile is called an F-3 profile (see Fig 2). Basic equations are:

$$x = C_1 t - C_2 \sin(2\pi t) - \frac{1}{3^3} C_3 \sin(6\pi t)$$
$$x' = C_1 - 2\pi C_2 \cos(2\pi t) - \frac{2\pi}{9} C_3 \cos(6\pi t) \qquad (6)$$
$$x'' = 4\pi^2 C_2 \sin(2\pi t) + \frac{4\pi^2}{3} C_3 \sin(6\pi t)$$

The harmonic content of the F-3 profile is shown in Fig 4. It contains two superimposed frequencies. The boundary conditions are: when $t = 1$, $x = 1$ and $C_1 = 1$; when $t = 0$, $x' = 0$ and

$$C_3 = \frac{9}{2\pi} - 9C_2 \qquad (7)$$

The acceleration x'' should be a minimum. From Eq (6) and (7):

$$x'' = 4\pi^2 C_2[\sin(2\pi t) - 3\sin(6\pi t)] + 6\pi \sin(6\pi t) \qquad (8)$$

When the expression in the bracket is zero, the acceleration is independent of C_2. This is when the acceleration is maximum. Therefore, setting the bracket equal to zero:

$$\sin(2\pi t) - 3\sin(6\pi t) = 0$$

Using trigonometric identities:

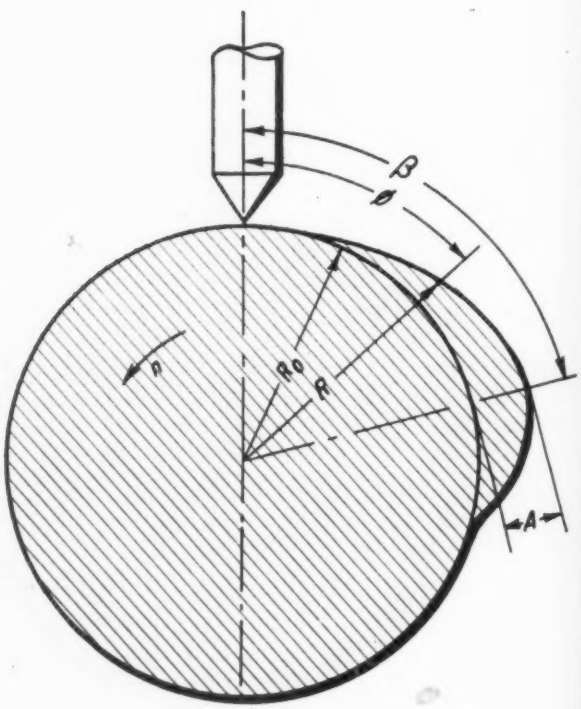
$$\sin 3\alpha = 3\sin\alpha - 4\sin^3\alpha$$
$$\sin^2\alpha + \cos^2\alpha = 1$$

these values are obtained:

$$\sin(2\pi t) = \sqrt{\frac{2}{3}}, \qquad \cos(2\pi t) = \frac{1}{\sqrt{3}}$$
$$\sin(6\pi t) = \frac{1}{3}\sqrt{\frac{2}{3}}, \qquad \cos(6\pi t) = -\frac{5}{3}\frac{1}{\sqrt{3}} \qquad (9)$$

By differentiating Eq (8), the rate of change of acceleration, or "jerk", is

$$x''' = 8\pi^3 C_2[\cos(2\pi t) - 9\cos(6\pi t)] + (6\pi)^2 \cos(6\pi t)$$



5 . . Polar coordinate system

TABLE II . . **Coordinates**

ϕ DEGREE	ϕ RADIANS	12ϕ DEGREES	36ϕ DEGREES
0	0	0	0
1	0.0174	12	36
2	0.0351	24	72
3	0.0523	36	108
4	0.0699	48	144
5	0.087	60	180
10	0.175	120	0
15	0.261	180	180
20	0.350	240	0
25	0.436	300	180
30	0.523	0	0

Inserting values of Eq (9) into the previous equation

$$x''' = 8\pi^3 C_2\left[\frac{1}{\sqrt{3}} + \frac{15}{\sqrt{3}}\right] - (6\pi)^2\frac{5}{3\sqrt{3}}$$

To obtain minimum acceleration, set $x''' = 0$. This yields (with the aid of Eq 7):

$$C_2 = \frac{15}{32\pi}, \qquad C_3 = \frac{9}{32\pi}$$

Inserting constants C_1, C_2 and C_3 into Eq (6) gives the equations for the profile, velocity, and acceleration.

$$\begin{aligned} x &= t - \frac{15}{32\pi}\sin(2\pi t) - \frac{1}{96\pi}\sin(6\pi t) \\ x' &= 1 - \frac{15}{16}\cos(2\pi t) - \frac{1}{16}\cos(6\pi t) \\ x'' &= \frac{15}{8}\pi\sin(2\pi t) + \frac{3}{8}\pi\sin(6\pi t) \\ x''' &= \frac{15}{4}\pi^2\cos(2\pi t) + \frac{9}{4}\pi^2\cos(6\pi t) \end{aligned} \tag{10}$$

Eq (9) gives the time when maximum acceleration occurs at this time ($x''' = 0$):

$$x'' = 2\pi\sqrt{\frac{2}{3}} = 5.15$$

This is 129% of the acceleration of the parabolic profile (5.15/4 = 1.29), or 82% of the acceleration of the cycloidal profile. The parabolic, cycloidal and F-3 profiles are compared in Table I.

Additional cam profiles, with forcing frequencies ranging from $f = 5$ to $f = \infty$, can be constructed so that there exists a family of profiles between the parabolic and cycloidal cams. The choice of the best profile depends on the natural frequency of the follower system. The next order cam is an F-5 profile. Here, an additional term in Eq (4) is retained, and the exciting frequency becomes $f = 5$. The maximum acceleration is lowered to a value below $x'' = 5.15$.

Example—Design of an F-3 cam

The analysis thus far has considered rectangular coordinates. For practical applications, these results have to be converted to cam cycles and cam strokes expressed in polar coordinates, Fig 5. Given the following values:

Stroke = A, in.
Cam Cycle = β, radians
Polar Coordinates = R_1, ϕ(ϕ ranging from 0 to β, see Fig 5)

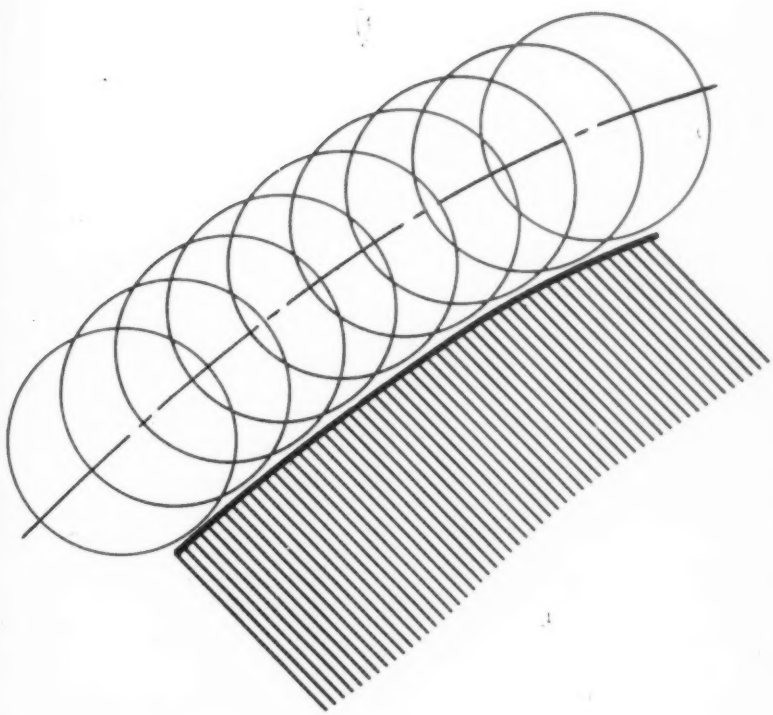
Eq (10) can be expressed in polar coordinates:

$$R = R_0 + \frac{A}{\beta}\phi - \frac{15}{32}\frac{A}{\pi}\sin\left(2\pi\frac{\phi}{\beta}\right) - \frac{A}{96\pi}\sin\left(6\pi\frac{\phi}{\beta}\right) \tag{11}$$

continued, next page

for an F-3 cam

SIN (12ϕ)	SIN (36ϕ)	R INCHES
0	0	4.000
0.208	0.588	4.0004
0.407	0.951	4.001
0.588	0.945	4.004
0.743	0.574	4.010
0.866	0	4.018
0.866	0	4.103
0	0	4.250
−0.866	0	4.411
−0.866	0	4.485
0	0	4.500



6 . . Envelope of circular follower

This is the working equation of a cam with stroke, A

From dwell position: R_0,
To dwell position: $R_0 + A$

In time: $\frac{\beta}{2\pi n}$, sec

With a forcing frequency, $f = \frac{6\pi n}{\beta}$

Eq (10) is for a point-like follower. The profile for other followers is obtained by an envelope of the follower shape, Fig 6, moving over the profile for the point-like follower. This principle can be used to generate a cam profile by moving a cutting tool in accordance with Eq (11) while the cam blank is rotating.

The harmonic analysis has to be extended to each rise or fall of the profile which is followed by a dwell. It then includes all frequencies of the complete cam cycle. Let us apply Eq (11) to a numerical example. Given:

$R_0 = 4$ in.
$A = \frac{1}{2}$ in.
$\beta = 30°$
$n = 300$ rpm

Solution: $\beta = \frac{2\pi}{360}(30) = 0.523$ radians

$n = \frac{300}{60} = 5$ rps

Maximum forcing frequency of an F-3 cam is:

$$f = \frac{6\pi n}{\beta}$$

$$f = \frac{6\pi 5}{0.523} = 180 \text{ cps}$$

Design the natural frequency of follower system to be about twice as high, or $f_n = 360$ cps. This may require a rather stiff follower system.

The points for the cam profile can be obtained from Eq (11):

$$R = 4 + \frac{0.5}{0.523}\phi - \frac{15}{32}\frac{0.5}{\pi}\sin\left(\frac{2\pi}{0.523}\phi\right) - \frac{0.5}{96\pi}\sin\left(\frac{6\pi}{0.523}\phi\right)$$

$$R = 4 + 0.96\phi - 0.075\sin(12\phi) - 0.0017\sin(36\phi)$$

This equation is solved for values of ϕ in 5° intervals in Table II. Values for $\phi = 1°$, 2°, 3° and 4°, are also included to show the influence of the sin (36ϕ) term.

The maximum acceleration is obtained as follows:

From Eq (11) by differentiation

with $\phi' = 2\pi n$

and $\phi'' = 0$

one obtains

$$R'' = \frac{15}{2}\pi^3 n^2 \frac{A}{\beta^2}\sin\left(2\pi\frac{\phi}{\beta}\right) + \frac{3}{2}\pi^3 n^2 \frac{A}{\beta^2}\sin\left(6\pi\frac{\phi}{\beta}\right) \quad (12)$$

By comparing Eq (12) with the equation for x'' in Eq (10), it will be noted that there is a factor of

$$\left(\frac{2\pi n}{\beta}\right)^2 A$$

that must be equated between the equations for R'' and x''. Therefore

$$R''_{max} = \left(\frac{2\pi n}{\beta}\right)^2 A x''_{max} \quad (13)$$

Inserting the numerical values for the F-3 cam into Eq (13) results in

$$R''_{max} = \left(\frac{2\pi 5}{0.523}\right)^2\left(\frac{1}{2}\right)(5.15)$$

Hence

$$R''_{max} = (60)^2(\tfrac{1}{2})(5.15) = 92{,}500 \text{ in./sec}^2$$

For a cycloidal (or F-1 cam) the maximum acceleration would be

$$R''_{max} = (60^2)(\tfrac{1}{2})(2\pi) = 140{,}000 \text{ in./sec}^2$$

Thus it can be seen that the F-3 profile resulted in approximately two-thirds the acceleration of a cycloidal profile.

For **reprint** of above article, just check 643 on one of the Reader Service cards found in this issue.

EDITOR'S NOTE: Detailed information about F-5 profiles is available from the author.

For other aspects of cam design, such as cam manufacturing methods, cam mechanisms, and evaluation of other types of cam profiles, see these articles:

When plastic cams are better, Aug 8 '60, p 44—In production quantities of 100 or more, plastic cams can be molded to closer tolerances and higher uniformity than steel ones machined one at a time.

New equations speed design of circular-arc cams, Mar 21 '60, p 58—Circular-arc cams are made up of a series of concave or convex arcs, or tangents. Such cams are cheaper to manufacture and find use when speeds and masses are moderate.

Roll cams: they stop and go on demand, Jan 19 '59, p 68—Gives graphical method for design of simple cam-like mechanisms that give a prescribed motion when triggered.

15 Ideas for cam mechanisms, Aug 3 '59, p 56—Diagrams and brief description of a variety of ways in which cam mechanisms can be put to work.

Computers simplify solutions of polynomial cam curves, Mar '57, p 196—Gives equations for cam contours, curve-fitting methods, comparison of polynomial curves and use of computers in solving cam problems.

Which way to make a cam? Mar 3 '58, p 67—Discusses 11 ways for cam manufacturing and their effect on accuracy and choice of cam types.

Other problems in the design of cams, such as the design of cam followers and springs and calculations of pressure angles are covered in a 48-page reprint, **Plate cam design.** Single copies available at $2 from Inquiries Service Department, Product Engineering, 330 W 42nd St, New York 36.

Cam control gets more out of a planetary gear, Jan 4 '60, p 38—By incorporating a grooved cam you get a novel mechanism that's able to produce a wide variety of output motions. Sample design problem included.

Limitations on cam pressure angles, Jan '57, p 193—Selection of the maximum pressure angle is based on the distribution of forces in the cam follower: Four types of cam followers are analyzed—overhead, system with a secondary follower, flat-faced follower, oscillating roller.

Miniature size cam as determined by pressure angle, July '56, p 141—Formulas, tables and nomogram for selecting the minimum size of cam to keep pressure angle under a specified value.

Surge waves in compression springs, Aug '57, p 167—Article analyzes how fast do springs expand, and what is the maximum velocity that a spring can attain. Many of the simplified theories employed for such calculations lead to inaccurate results. —*Nicholas Chironis*

Work forges ahead on

Full-size monorail

Seattle project, based on Alweg design, will be in operation by April. Japan is planning one on a Lockheed Aircraft design.

PROSPECTS for full-scale passenger carrying monorails are brightening. Last year, the Italians built a mile-long system, based on the Alweg design, for the "Italia 61" exhibition in Turin. Several others are under way:

- In Seattle, a monorail based on the Alweg system is being constructed to carry passengers from the central shopping district to the fair grounds. Service will start in April and after the fair closes in October the monorail may be incorporated into a rapid-transit system for Seattle.
- The Austrians are planning a 4-mi monorail as part of Vienna's tramway system. It is also based on the Alweg concept and will be partially financed by Krupp of Germany.
- In Japan, a new company — Nihon Lockheed Monorail—has been formed to build a 4-km line from Nikko, a resort area north of Tokyo, to Kirifuri Falls. This system, based on a Lockheed Aircraft Co design, is expected to be in service by the latter part of 1962.

The Lockheed monorail, like its Alweg cousin, is a saddle-type car straddling a single rail. Each car is supported by two trucks, each having two 24-in. dia drive wheels and six stabilizing wheels. Lockheed chose a steel-rubber sandwich design for the wheels. Each drive wheel is powered by a 100-hp 600-v dc motor. The monorail will attain speeds of 75 mph with accelerations of 3.5 mph per sec.

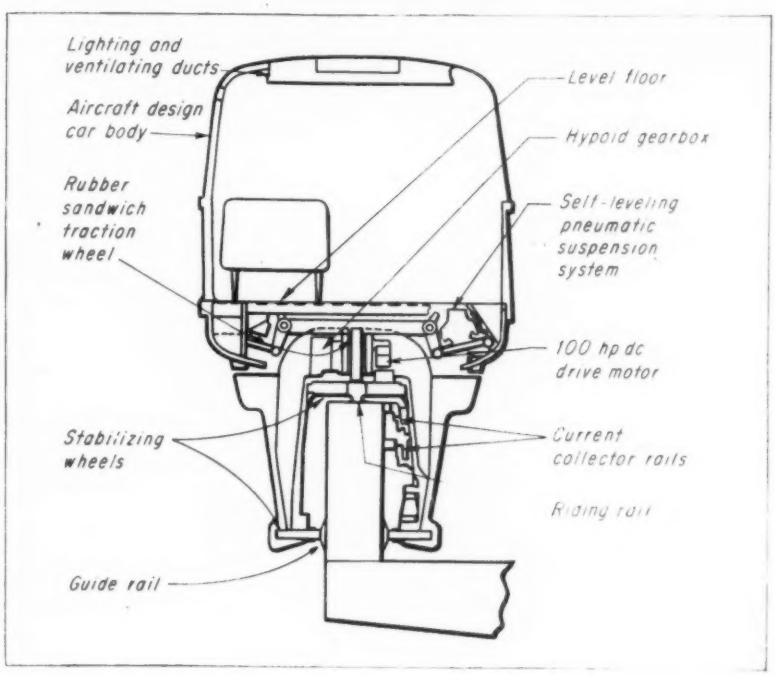
The truck includes a suspension system composed of independent air springs for vertical suspension, 4 torsilastic springs for lateral suspension and two shock absorbers. This system operates automatically, to maintain floor level constant at stations despite changing passenger load.

Lockheed has said the materials and design philosophy borrow heavily from aircraft. Car weight will be minimized by using aircraft-type stressed skin panels of light alloy metals. The floor will be solid aluminum. Another adaptation from aircraft will be soundproofing materials to reduce noise within the cars.

In Alweg's Seattle monorail, guide and drive wheels are pneumatic and powered by 600-v dc motors. In event of deflation, solid rubber wheels of somewhat smaller diameter, located near each of the vertical and horizontal guide and drive wheels, engage the beam.

The Alweg speed-control system is fully automatic, adjusting train speed to the layout of the track. The braking system is automatic. Each train is 120 ft long and 10 ft wide. **end**

CONSTRUCTION of the mile-long Seattle monorail (above) nears completion. It will have two trains of four cars each. Meanwhile, final designs for the rail, truck and cars of the Nihon Lockheed monorail (below) are being readied.



Shortage of the 1960s will be

Engineers, not scientists

National Science Foundation study improves method of measuring engineering demand, but still finds that demand outruns supply.

JUST how many scientists and engineers will we need by 1970? And are our educational facilities training enough people to fill this need?

The National Science Foundation considers a reliable answer to these questions one of its important obligations. Accordingly, it has released a major study that attempts an improved method for getting such data. In the process, the study reaches some not entirely surprising conclusions: the number of available engineers will fall about 14,000 a year short of the number that could be employed effectively during the 1960's. On the other hand, it finds the supply of scientists will nearly fill the demand.

In reaching these conclusions, the study says that requirements for engineers and scientists to fill openings in industry and government will rise from 1,096,000 in 1959 to 2,032,000 in 1970—an increase of 85%. (It's interesting to note that a forecast by NSF earlier this year put employment of scientists and engineers in 1970 about a half million higher at 2.5 million.) The demand for engineers will rise from 783,000 in 1959 to 1,484,000 in 1970; for scientists from 313,000 to 548,000.

To fill its vacancies, the engineering profession will need 81,000 recruits annually to replace losses through retirement, and other causes, and to fill new job openings. But annual additions to engineering personnel will probably run about 67,000.

In making these projections, the NSF put special effort into getting a more realistic estimate of demand—this is generally considered the weakest link in previous analyses. The usual procedure is to compute the annual increment in number of engineers employed over past years and project it into the future. But such gross projections do not reflect changing economic and technical trends in various industries, changing demand for various specialities, or skewing of results by temporary and erratic spurts in employment.

The improved NSF forecast was reached by adding together the projected requirements for scientists and engineers in individual companies that had participated in earlier NSF surveys. These projections were obtained on the basis of trends in both technical employment and total employment in the company. By linking the projection to total employment, such factors as US population growth, shifting consumer preferences and technological developments are presumably infused into the final calculation.

Credibility of these statistical calculations was then verified through extensive interviews with technical directors in the chemical and electrical machinery industries. These are the two largest employers of technical personnel.

As a result of such "informed judgments", projected needs for scientists and engineers in the electrical equipment industry over the ensuing decade were reduced about 15% from 250,000 to 211,000. But the original projections for the chemical industry were retained.

A realistic projection of supply also poses some procedural questions: how many scientists and engineers now working will leave the profession because of death, retirement, or change of career? How many will enter it without benefit of formal training? How many students enrolled in technical curricula will choose careers in sales, management, or nontechnical areas?

Of the total demand for new engineers, some 17,000 recruits will be needed to make up for losses to the profession through attrition. The remainder will fill newly created jobs. The new engineers come from two major sources: engineering school graduates and technicians who work into engineering positions through experience. The latter group has accounted for 23% of the total in recent years. If this rate persists, about 19,000 new engineers a year will be nondegree holders.

Past experience indicates that about 14% of graduating engineers will take employment in other fields. If these losses continue, the engineering schools will have to graduate 72,000 engineers a year to fill the nation's need. In 1960 slightly less than 46,000 degrees were awarded. Chances are the present decade will witness an increase because total enrollments are rising. If engineering enrollments remain at the present ratio to total enrollments, the number of bachelor's degrees awarded during the next decade will average about 48,000 a year and all engineering degrees about 58,000—well below the required 72,000.

A recent study by the Engineering Manpower Commission of the Engineers Joint Council is even less optimistic. The EJC reports that engineering enrollments have been declining in relation to total enrollments in recent years. If this trend persists, the EJC predicts that engineering schools will award only 32,000 bachelors degrees in 1965 despite increased number of students.

Scientists, too, will be in somewhat short supply. Only about 2% enter the field without degrees. And losses among those getting degrees are sev-

ere—roughly 70% of science graduates go into secondary school teaching, related professions as medicine or nontechnical jobs. If this trend persists, educational institutions will have to graduate 83,000 scientists a year to fill the need. With expanding enrollments, the universities will probably graduate about 80,000 scientists a year during the 1960's. This leaves a deficit, though it is by no means as severe as engineering deficit.

The NSF hopes to improve these statistics as time goes on. The data on demand for scientific and engineering employment in colleges and government, particularly local government, are rough. And industrial data, if built up on an establishment rather than company basis, would provide a more detailed breakdown for industry and highlight changing growth rates among different segments.

Demand will nearly double in decade

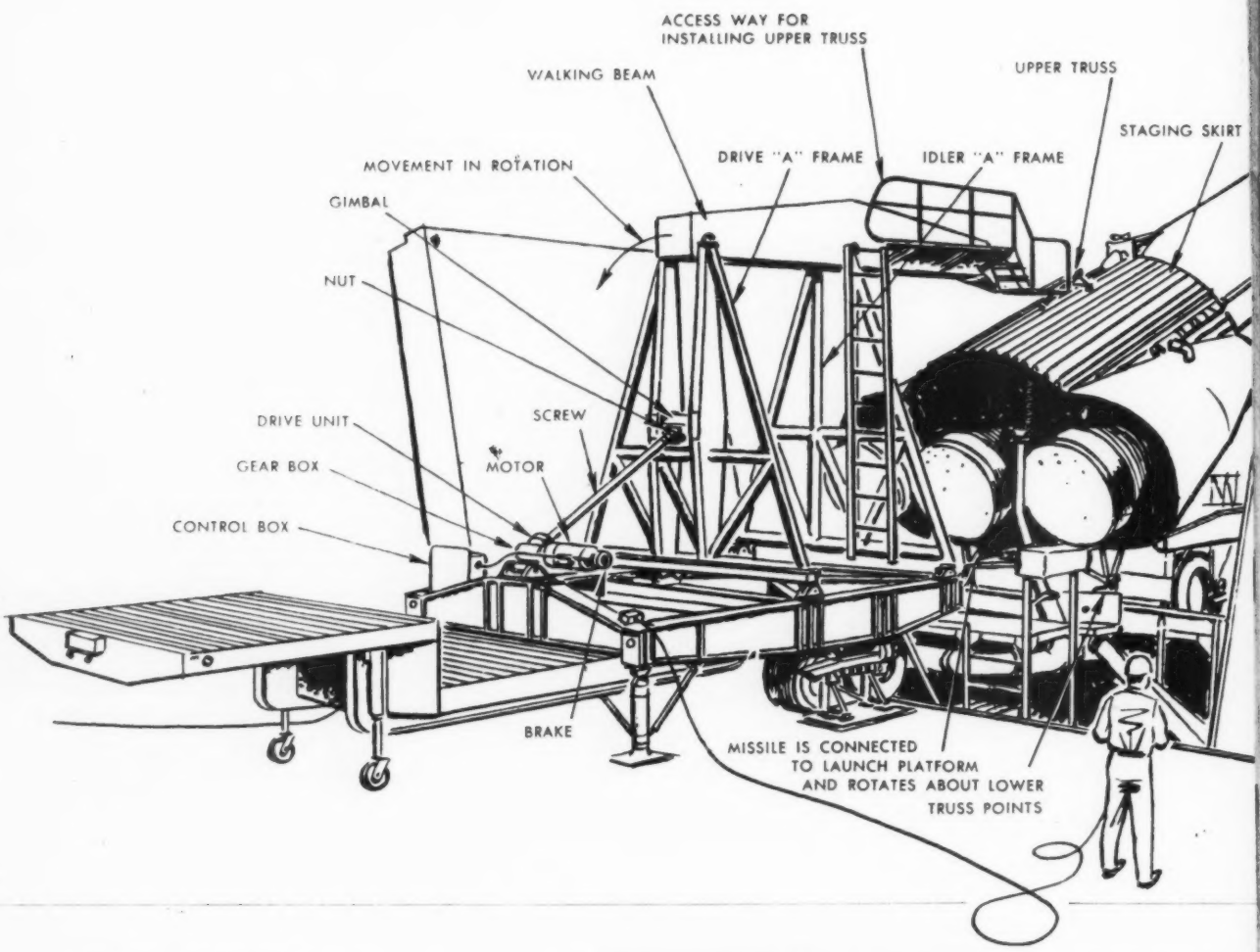
	ENGINEERS & SCIENTISTS	
	1959	1970
Industry	808,100	1,561,200
Colleges	112,300	176,400
Federal government	101,400	164,300
State government	39,400	73,100
Local government	30,000	49,600
Miscellaneous*	4,800	7,400
Total	1,096,000	2,032,000

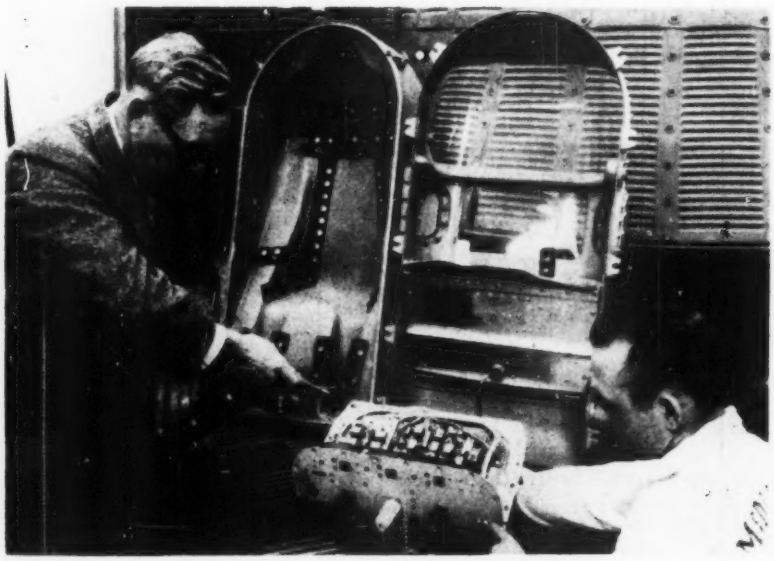
*Includes commercial and noncommercial farms, private hospitals, certain public hospitals, commercial labs, etc.

Industry will need larger portion of technical men by 1970

INDUSTRY	TOTAL EMPLOYMENT		EMPLOYMENT OF ENGINEERS & SCIENTISTS		TECHNICAL AS % OF TOTAL EMPLOYMENT	
	1959	1970	1959	1970	1959	1970
Mining	647.6	833.4	30.5	79.5	4.2	8.6
Construction	1,298.5	2,008.6	53.7	110.6	3.4	4.5
Manufacturing	15,830.4	20,643.5	568.0	1,140.0	3.5	5.3
Food & kindred products	1,399.7	1,571.0	10.2	13.4	0.7	0.9
Textiles & apparel	1,771.0	1,973.0	5.4	6.5	0.3	0.3
Lumber & furniture	625.4	705.2	2.9	3.9	0.5	0.6
Paper & allied products	574.9	795.8	9.7	21.3	1.7	2.7
Chemicals & allied products	920.4	1,221.4	83.1	151.5	9.0	12.4
Petroleum refining; petroleum, coal products	371.4	445.5	28.0	39.1	7.5	8.8
Rubber products	307.8	400.4	7.3	10.5	2.4	2.6
Stone, clay & glass	506.2	667.0	9.2	15.0	1.8	2.4
Primary metal products	1,257.1	1,657.4	33.2	66.3	2.6	4.0
Fabricated metal & ordnance	1,148.3	1,387.5	34.7	78.5	3.0	5.7
Machinery	1,599.4	2,257.7	67.4	125.5	4.2	5.6
Electrical equipment	1,217.5	2,059.3	92.7	211.0	7.6	10.2
Transportation equipment	2,037.9	2,866.3	130.8	292.4	6.4	10.2
Prof. & sci. instruments	343.0	531.4	23.7	49.3	6.9	9.3
Miscellaneous manufacturing	1,750.3	2,104.7	7.7	10.3	0.4	0.5
Transp., communication, & public utilities	3,800.1	4,418.6	59.5	84.8	1.6	1.9
Eng. & archit. services	185.2	238.0	56.1	72.1	30.3	30.3
Medical & dental labs	12.3	15.6	1.0	1.3	8.0	8.4
Misc. business services	296.4	377.8	7.0	12.3	1.5	2.1
Nonprofit organizations (1958 & 1970)	26.3	34.3	6.0	7.9	22.9	22.9
Other manufacturing	6,475.8	8,640.0	26.3	52.7	0.4	0.6

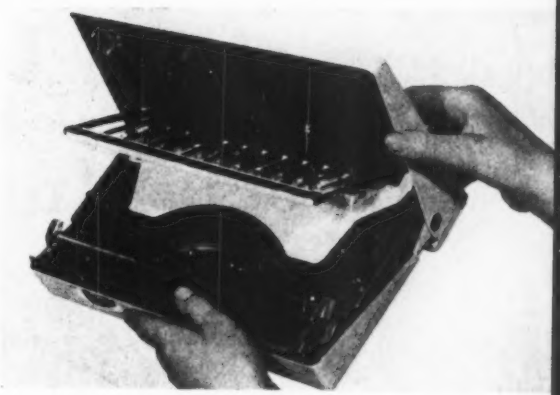
PANORAMA



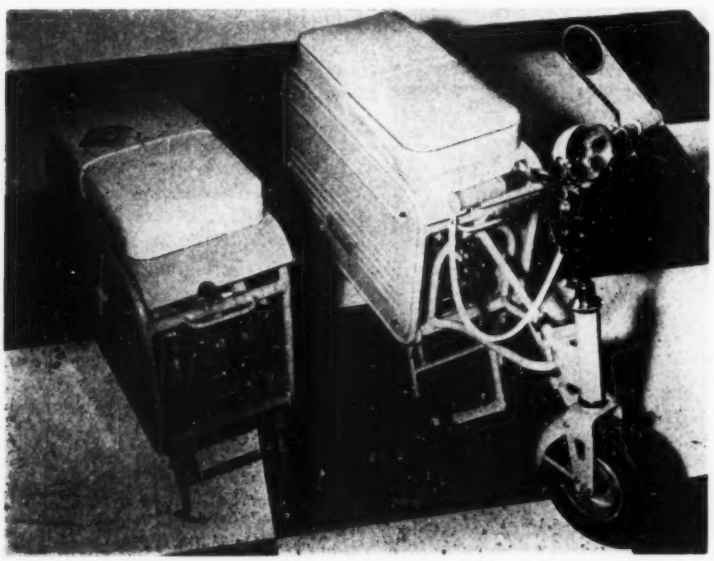


ENOS' SPACE SUIT on his recent two-orbit Project Mercury trip of the earth was this pressure-tight container with windowed dome. McDonnell Aircraft, designers of the space couch, report the spacecraft's environmental control system located beneath the couch maintained a livable, gaseous atmosphere of 100% oxygen at room temperature at a pressure equivalent to 27,000 ft altitude. Electronic unit is the "psychmotor" which fits into container door at waist height. Unit is programed so that chimp must pull certain levers at stated intervals and pick-out different objects in the tiny glass panels by pressing the lever beneath the proper panel. If correct, a banana-flavored pellet is ejected at lower right (finger pointing); if wrong, the chimp gets a mild shock in left foot. G. E. Younger, senior design engineer, and D. W. Bennett, instrumentation engineer, said that this machine when originally designed stood 6-ft high. Redesign and use of microminiature parts cut size to 6 in. permitting use in confined area.

MANHANDLING AN ATLAS missile from truck trailer to silo launch platform requires delicate manipulation. To do it, engineers at General Dynamics Astronautics had engineers at Saginaw Products Corp design a ball screw drive actuator that will raise the 80-ft long, 10-ft dia, 6-ton missile in 60-mph winds. Erector drive unit is designed around a 3-in. ball screw traveling through a fixed, trunion-type nut, and driven by a two-speed, 7.5-hp motor fitted with a fail-safe disk brake. In operation, the unit is secured to the drive member of a simple parallel mechanism, designed by Astronautics, consisting of two "A" frames connected to a walking beam. The beam is secured to the attach point on the missile's staging skirt. When the erector is retracted, the missile is pivoted to a vertical position by cantilever action. The traveling nut is mounted in a gimbal secured to the driven "A" frame of the parallel mechanism. Nut stops are laminated of a compressible material, absorbent enough to minimize shock, yet rugged enough to stall out the motor. The magnetic brake and mechanical self-locking feature designed into the worm gearing give additional safety. The strictly mechanical gear drive provides a positive positioning lock at any point in the horizontal travel. Thus, in the event of power failure, the missile will remain in position. Only one man, at remote control, is needed during erection.



COLLAPSIBLE TYPEWRITER, invented by Swiss engineer Marcel Fresard, measures only 11 x 6.6 x 1.9 in. when closed—small enough to fit into a brief case cosily—and weighs only 5.5 lb. When opened, the machine is 11 x 11.3 x 4.5 in. The svelte shape results when the keyboard folds through a 180° over the carriage and type-carrying bars. Each keybar is attached to a common shaft through a rocking lever. A pusher cam, pivotally secured to an axis parallel to the shaft, actuates the rocking levers to fold the machine. The unit will go into production late next year.



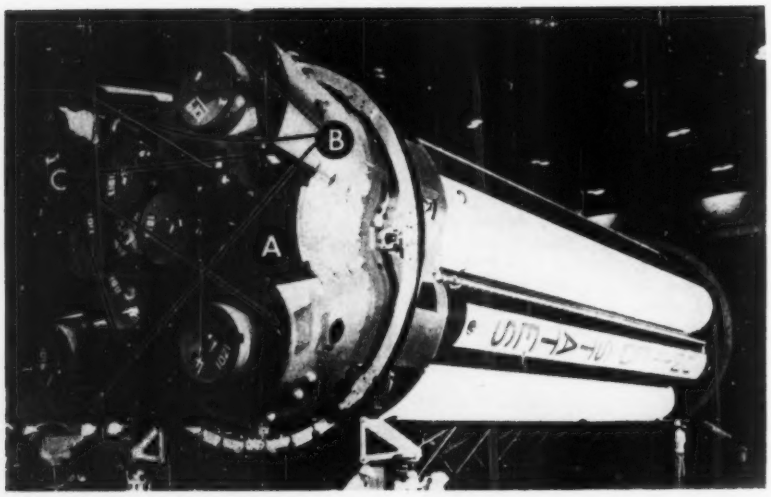
JAPANESE FOLDING SCOOTER, designed by a Swiss engineer, made its American debut at the Japan Trade Center Light Machinery Show. The 92-lb scooter gets 165 miles per gallon at a top speed of 35 mph. A 2.8-hp, two-cycle engine drives through an automatic transmission. Engine and transmission are fully enclosed in scooter body. Handlebar twist grip operates throttle and handlebar lever operates internal expansion brakes. Valmobile folds into its own body shell to make a 27½ x 13½ x 24½ in. package. The Gosho Trading Co, Inc, holds rights to the design being manufactured by Hirano Seisakusho, Ltd, of Nagoya, Japan. Suggested retail price is $245.

Saturn success aided by

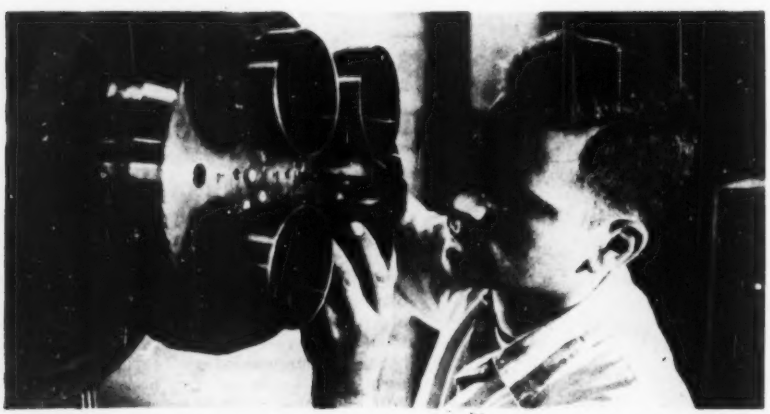
Special insulation

Abalation of lower structure caused by reversal of exhaust gases is temporarily relieved by high-temperature insulation.

R J WARD JR, Huntsville news bureau



INSULATION at base of the 22-ft-dia, 80-ft-tall Saturn booster is in three locations: (A) Shield protecting section above the engines from jet radiation; (B) interior surface of aerodynamic shroud around base; and (C) curtains around each of eight engines. Insulation will be varied on later models.



ROCKET NOZZLES are adjusted during investigation of heating phenomenon at Cornell Aeronautical Laboratories. Pressure transducers are set behind orifices in base plate. Instruments at surface of base are thin-film thermometers.

CONVECTIVE and radiative heating of the lower structure of multi-engined rockets can be controlled by insulation, say engineers at the NASA George C Marshall Space Flight Center, Redstone Arsenal. The intense heat ablates the lower structure and destroys critical control and flight components. The convection currents are caused by the interaction of exhaust plumes with a resultant back flow. In addition, radiative heating is present from the exploding exhaust gases which, in the case of Saturn, approach 4500 F. Without insulation, it is believed, the big booster would fail before reaching 500 ft.

Insulation is placed in three areas (see picture, left) with the heat curtain posing the most difficult problem. It had to be flexible, as the four outer engines swivel for vehicle guidance, and withstand a high-*g* load and vibration.

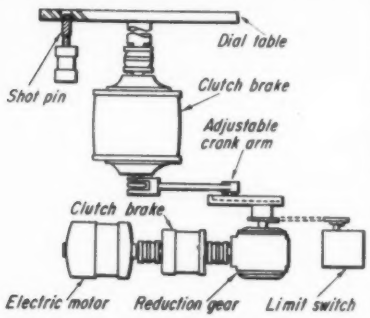
Because of its strength characteristics, fiberglass is used as the basic curtain material. Being brittle as well as strong however, the fiberglass is insulated with silicone rubber, a silica-fiber fabric and a reflective coating.

For protection of the stationary plates above the engines and the interior of the shroud, a plastic was developed consisting of a combined epoxy-phenolic resin system filled with asbestos fibers. The plastic is only 70-80% cured before flight because cost of full air-curing is prohibitive and maximum effectiveness is obtained by completion of the curing process during flight. This innovation of curing during flight, reports NASA engineers, enables a better insulation characteristic than any commercially available —and at about 1/5 the cost. To safeguard against radiant heat effects, a highly reflective coating is applied over the basic plastic insulation.

Engineers say that at lift-off, the coating, an aluminized fiberglass-cloth tape, lasts about 30 seconds, sufficient time to reduce radiant heat below any insulation breakdown point. After the reflective coating is burned away, the basic insulation remains to protect components during the balance of the flight.

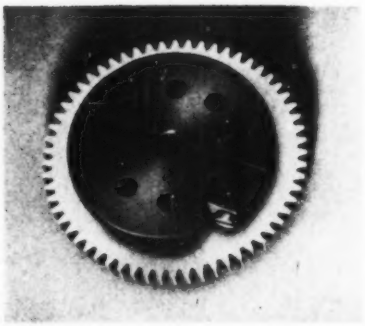
The insulation developed by the Marshall Space Center group is being applied to only the first four of the planned ten Saturn vehicles. Insullating material beginning with the fifth booster will be chosen after heat data from the early flights are studied. In addition, exhaust-plume reversal is being studied for NASA by subcontractors in hopes of finding a solution which would not rely on an insulating material. **end**

NEW COMPONENTS



Indexing drive is adjustable . . . and was originally designed for welding machine. Consists of electric motor, two clutch brakes (one of larger rating than other), fixed-ratio reduction gear and an adjustable two-piece crank arm. Multicircuit limit switch controls sequencing of both clutches. Electric motor runs at all times that system is operating, locked into input side of clutch. In operation, both clutches are energized during first 180° of crank arm travel—dial table is also indexed at this time. At null point, large clutch is de-energized and dial table is held in desired position by air-operated shot pin. Small clutch returns crank to start position. **National Electric Welding Machines Co, Bay City, Mich.**

Circle 300 on Reader Service Card

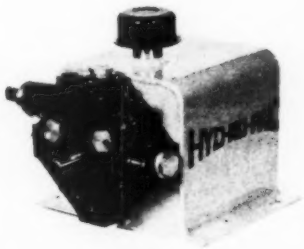


Clutch gives constant slip torque to 3 in.-lb, preset at factory. Consists of output hub with integral gear, piloted on input hub. Pin on face of input hub fits between ends of single-turn spring fitted to output hub. Torque normally is transmitted via spring, but when output torque exceeds slip rating, spring will slip on output hub. With additional springs, slip torque max can be raised to 35 in.-lb. Made of sintered metal, oil impregnated. **Precision Specialties, Inc, PO Box 118, Pitman, NJ.**

Circle 301 on Reader Service Card

Solenoid has parallel coils . . . for high pulling force, arranged so that plunger motion disengages one coil from circuit so minimum current is required during hold part of cycle. Designed for 27 v dc, 0.7 amp holding current, with 38 lb force. Temperature range is −65F to 165F. **Scanner Corp of America, 30595 W Eight Mile Road, Livonia, Mich.**

Circle 302 on Reader Service Card



Hydraulic pump with integral valve which can be changed quickly from one-way (for single acting cylinder) to two-way. For pressures to 3500 psi and capacities to 10 gpm, these pumps are said to be efficient over full range of permissible speeds, 1 to 1800 rpm. Can be driven by belt, gear, hand crank or power take-off. Rotation can be clockwise or counter-clockwise without changes. **Mechanical Devices Co, Bloomington, Ill.**

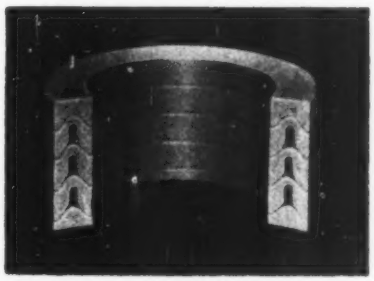
Circle 303 on Reader Service Card

Static relay actuates solenoid . . . to switch heavy inductive loads without arcing. Contact used in relay is a bi-stable semiconductor. Full-wave rectifier, unfiltered, producing 60 cps line voltage actuates solenoid. Device operates on 105 to 127 v supplies, 60 cps, over ambient temperature range of 0 to 50 C. **Kidde Electronic Laboratories, Walter Kidde & Co, Inc, Belleville 9, NJ.**

Circle 304 on Reader Service Card

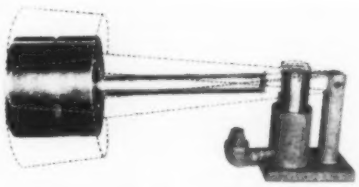
Relay with mercury-wetted contacts consists of glass capsule containing reservoir of mercury and SPDT contact assembly. Capillary action of mercury renews contact surfaces with mercury film with every operation. From one to four contact capsules can be combined in a single steel enclosure, providing relays of 1, 2, 3, 4 poles, double throw. Operating time for single-capsule relay is less than 3 millisec, using 2 w. Release time is about 3.2 millisec. Can be driven 100 times per second. Contact ratings are 500 v, 5 amp, to 250 va with contact protection. **Potter & Brumfield, Princeton, Ind.**

Circle 305 on Reader Service Card



Molded Teflon packing . . . for valves, pumps and instruments in corrosive service has a hinge-like center section said to permit operation of rods, stems or pistons with minimum friction at all pressures. Temperature range is −120F to 500F, pressures to 1000 psi. Available in ring form only. **Garlock Inc, Palmyra, NY.**

Circle 306 on Reader Service Card

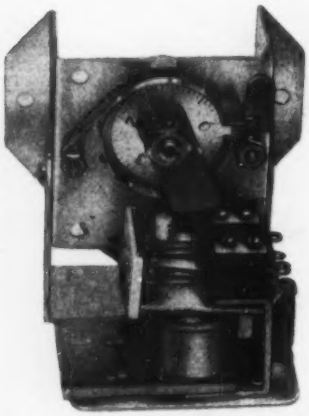


Fixed pressure on mechanical seals is provided for systems requiring sealing liquid and where pumps for circulating liquid are not necessary or not available. Lowering of weight-and-lever assembly indicates leakage. All steel construction is standard. For use in conjunction with double mechanical seals using Hastelloy, carbon steel or ceramic seal faces. **Economy Mfg. Co, Railroad St, Box 755, E Liverpool, Ohio.**

Circle 307 on Reader Service Card

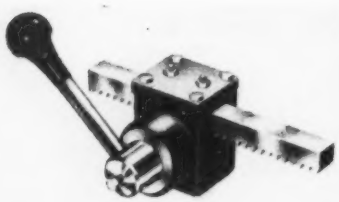
Interval or delay timer . . . consists of three functional components: motor and trip arm, holding coil, motor-load switch rack with two sets of SPDT units. When operated as a delay timer, adjustable trip arm causes switch to energize coil, pulling down rack and tripping normally open

continued, page 56



load switch and shutting off motor. Available in adjustable time ranges of 14, 57, 114 sec, and 4.5 and 9.5 min. For operation at 120 and 240 v ac, 50 or 60 cps. Motor rated at 5 w and coil at 6 w. **Haydon Div, General Time Corp, 245 Elm St., Torrington, Conn.**

Circle 308 on Reader Service Card

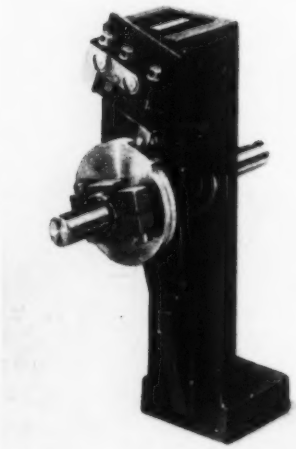


Rack-and pinion arbor head . . . available with ⅜-in, square arbor with max working force of 2/5 ton and ¾-in. square arbor with 1 ton rating. Can provide strokes up to 24 in. Full length gib plates are adjustable. **Dickinson & Assoc, 3334 N Central Ace, Glendale 3, Calif.**

Circle 309 on Reader Service Card

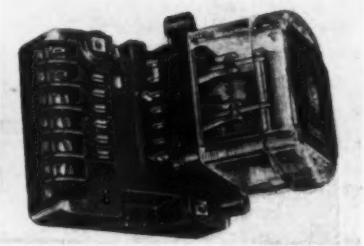
Toggle switch is ¼x¼x⅛ in. and was originally designed for turning on and off receivers of radio-controlled model airplanes, cars, boats. Except for silver-plated stainless spring and gold-plated bearing, switch is made of silver and has a 50-v, 1-amp rating. **Micro-Miniature Controls Div, Otarion Listener Corp, Box 711, Ossining, NY.**

Circle 310 on Reader Service Card



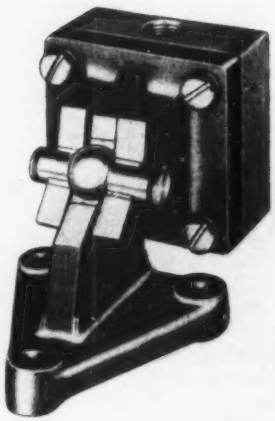
Adjustable stop reverses servo . . . and synchro components at predetermined positions. Consisting of cam assembly, SPDT switch and bearing hangers that are complete with bearings and shaft, cams are adjustable to actuate switch at any angular limit between 0.0° and 180° of shaft rotation. **Sterling Instrument, Div Designatronics Inc, 17 Matinecock Ave, Port Washington NY.**

Circle 311 on Reader Service Card



Stackable relays . . . rated at 10 amp, 300 v ac, were originally designed for control circuitry of machine tools and similar industrial products. Various contact arrangements are available, some as standard. Front-wired model is for surface mounting; plug-in front wired type is for use with plug-in receptacle. **Arrow-Hart & Hageman Electric Co, Motor Control Div, 103 Hawthorn St, Hartford 6, Conn.**

Circle 312 on Reader Service Card



Cylinder mount compensates . . . for up to ±3½° of misalignment in any plane. Consists of pivot having spherical bearing. Pivot has three-pad mounting surface said not to be effected by surface irregularities on mating part. **Alkon Products Corp, Hawthorne, NJ.**

Circle 313 on Reader Service Card

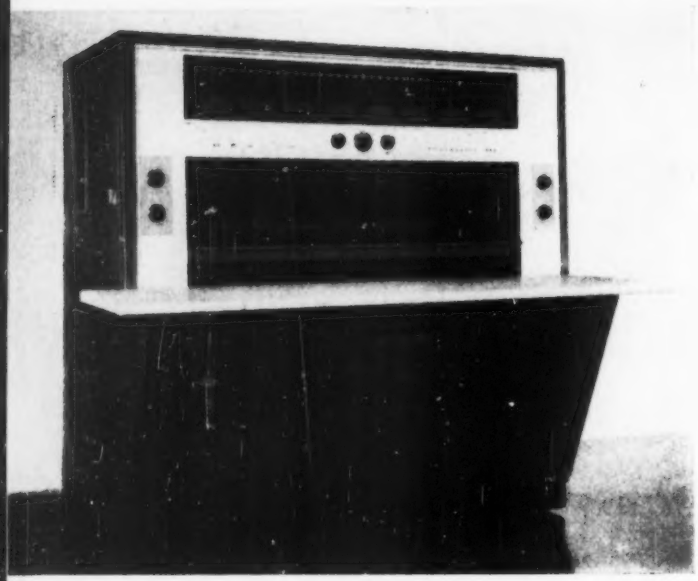
Shaft and flange-mounted reducers based on helical gearing provide speed ratios of 15:1 or 25:1, with power ratings to 125 hp and output torque to 100,000 lb-in. Fabricated 1⅛-in. steel housing has double-lip seals and dipstick for oil level check. **Falk Corp, Box 492, Milwaukee 1, Wis.**

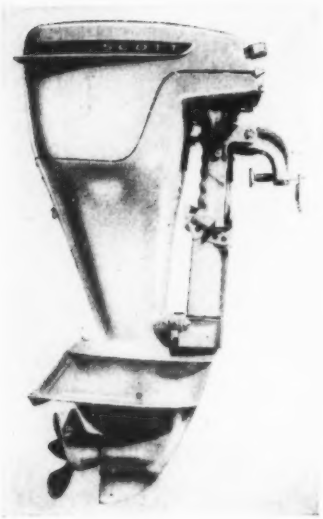
Circle 314 on Reader Service Card

Liquid-level gage . . . for use on gear cases, storage tanks, reservoirs and other equipment where visible check on contents over particular range is required. Available in three sizes, providing for level var-

continued, page 62

hodgman-bourke:
"there is no shortcut to good design"





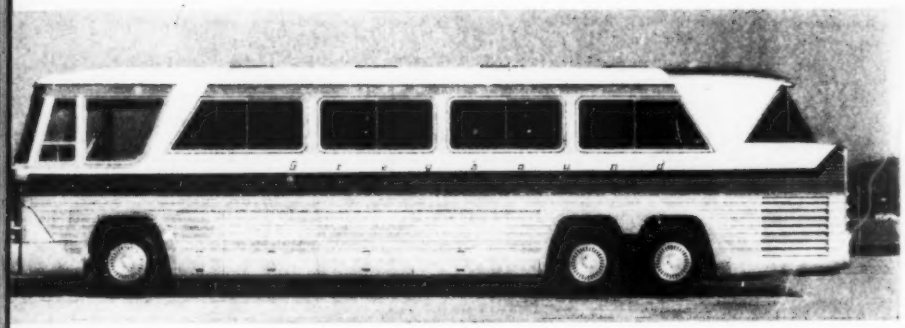
hodgman-bourke talk design

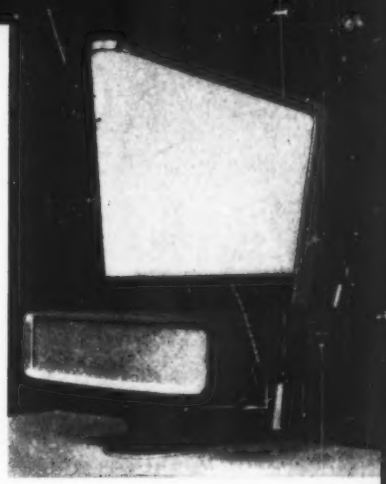
For two designers who founded their firm in 1955 with no clients, Clare Hodgman and Bob Bourke have come a long way. Their beginnings were modest, to say the least, but today they work on designs that range from trucks to cameras, vending machines to auto interiors, and many more. The secret of their success is really no secret at all: they simply design products that connote quality. To do this, a product should have what they call a "high index of desirability," i.e., convey thoughts of reliability and excellence of value.

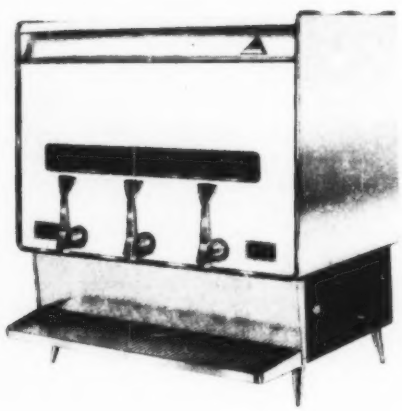
Both Clare Hodgman and Bob Bourke have extensive background in automotive as well as in major appliance design, two areas where appearance and function are of supreme importance in the immediate success or failure of a product. Before forming their own firm, their combined experience included work with Sears Roebuck and Company, General Motors, Studebaker Corporation, and numerous products for English clients, including work for major European automobile producers.

Hodgman and Bourke feel there is no actual formula for design, because each product is different. There are, however, certain ground rules that apply to *any* design, and if the rules are followed, the ultimate product will have their "high index of desirability." First, they feel that if a manufacturer can make a product that is carefully planned and designed and show it at the point of sale, backed with a competent engineering and sales organization, there is no limit to how far he can go. Here material selection is vitally important. The best material must be selected—for economy, workability, strength, appearance and long life. Although there is always the chance that competition will come out with an improved version of that product, the best insurance against this is consistent intelligent research and product improvement.

The designer, they feel, is of equal







importance in both cases. It is up to him to design a saleable product in the first place, then keep that product on top through design. "Countless products are manufactured with little or no thought given to their improvement," says Bob Bourke. "We all know that they are sold in large quantities through the artificial stimulus of merchandising stunts, high frequency advertising, etc. This is short-range marketing and the manufacturer is in a vulnerable position." This product will lose, Bourke feels, to the well-designed, constantly improved product.

The designer himself must have many qualities. He must understand the patterns of business to gain the confidence of his client. He must be realistic. He must be a good merchandiser, thoroughly versed in technical matters, and he must have a healthy respect for the various limitations inherent in mass production. A man like this, working with an enlightened client, can move a product toward commercial success.

The designer must have a thorough working knowledge of his materials. In their work with a wide range of consumer and industrial products, Hodgman and Bourke must be able to select the material that gives them maximum workability, strength and a wide variety of types and grades from which to choose. Little wonder, then, that so many of their products are made of steel. They feel that "if steel were invented today, we would think it was a miracle material." In many Hodgman-Bourke designs, steel is used for its great strength (trucks, for instance). In others (like appliances) for its long-established sales appeal. Although not all of their products are designed in steel, like most designers they feel that steel is the number one material for strength, versatility, economy and variety.

USS United States Steel

TRADEMARK

USS Design Steels: special solutions

Lower your costs and brighten your products with USS Bright Annealed Stainless Steel Strip

USS Bright Annealed Stainless Steel Strip with its desirable mirror finish requires less buffing in many applications and can save your money. In many cases, bright annealed Stainless Steel strip can be used with no costly buffing operation. U. S. Steel produces the strip by utilizing highly polished rolls which impart a smooth, dense surface on trim and molding stock that is carried through the annealing cycle by atmospherically controlling the furnace to give you, the product designer, a mirror finish and the full corrosion-resistant properties of Stainless Steel. Stainless Steel with its superior yield and impact strengths will resist dents, and scratching or cracking where other materials may fail.

In brief, USS Bright Annealed Strip offers a brighter finish and corrosion-resistant virtues of Stainless Steel. It can save you money in the products you design.

Drop us a note, and we will be pleased to send you a "production" sample. Write to United States Steel, Room 6434, 525 William Penn Place, Pittsburgh 30, Pa.

U. S. Steel first to develop rolled structural shapes from quenched and tempered alloy steels

Important weight and cost savings are possible with rolled structural shapes, made from quenched and tempered alloy steels now available from U. S. Steel. The new shapes are heat-treated to yield strengths as much as three times that of structural carbon steel. Furnished in standard I-beams, wide-flange, channels and angles, and in lengths up to 40 feet, the new shapes are produced from several U. S. Steel's best-known quenched and tempered alloy compositions, including "T-1" and "T-1" type A constructional alloy steels, 9% Nickel Steel for cryogenic applications, and HY-80 naval armor steel. Actually any alloy steel that derives its properties through heat treating can be made available.

These new rolled shapes will save the time and expense of cutting and welding plate material sections into structural shapes. Further information on these or our USS "T-1" plate steels is available from United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

Availability Quenched and Tempered standard structural shapes are available in the following shapes and sizes:

I	Beams: 8" to 16" Beams: 6" to 12" inclusive	Wide-Flange Sections and Foot Weights* American Standard Sections and Foot Weights*
[	Channels: 6" to 15" inclusive	American Standard Sections and Foot Weights*
L	Equal Angles: 3" to 8" inclusive	Standard Sections*
L	Unequal Angles: 3½" x 3" to 8" x 6" inclusive	Standard Sections*

Maximum Length 40' for all sections

*See our booklet, "USS Shapes & Plates," ADUCO-2/1001

Mechanical Properties of Quenched and Tempered Alloy and Armor Steel Structural Shapes

	Yield Strength psi	Tensile Strength psi	Elong. in 2", % Min.	Reduction of Area % Min.	Longitudinal Full-size Charpy Impact (when spec.)	
					Keyhole	V-notch
"T-1" Steel 2½" to ⅜"	100,000 (Min.)	115,000/ 140,000	18	55[1]	15 ft.-lbs. @ −50F	30 ft.-lbs. @ +10F
"T-1" type A 1" to ⅛"	100,000 (Min.)	115,000/ 140,000	18	55[1]	15 ft.-lbs. @ −50F	.....
Grade A 9% Nickel	60,000 (Min.)	90,000 (Min.)	22% Min.	...	15 ft.-lbs. @ −320F	20 ft.-lbs. @ −320F
Grade B 9% Nickel	65,000 (Min.)	95,000 (Min.)	20% Min.			
HY-80 ¼" to 2" Incl.	80,000 100,000[2]	.....	19[3]	...	.....	70 ft.-lbs. @ −120F

(1) ¼" and under—45% Min.
(2) ½" and over, yield strength range is 80/95,000 psi
(3) ½" to 2" inclusive, elongation 20% Min.

This mark tells you a product is made of modern, dependable Steel.

for special problems

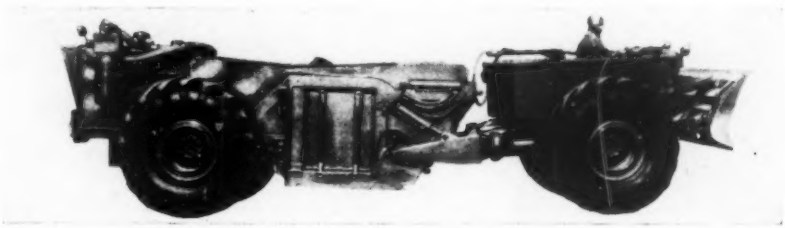
USS Par-Ten High Strength Steel makes bumpers stronger, better-looking, cuts costs

Bumpers of USS PAR-TEN High Strength Steel have 40% greater strength than ordinary carbon steel bumpers. In addition, they have high resistance to impact and a surface that takes an excellent chrome finish. With PAR-TEN Steel at a typical yield point of 45,000 psi, bumper weight can be reduced by as much as 20%. USS PAR-TEN High Strength Steel was developed especially for bumpers, bumper guards and similar

high-finish uses, It keeps superior surface characteristics even after severe grinding. It gives a gleaming chrome finish, yet provides increased resistance to denting and impact. Detailed information is available. Write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

This tractor flies in a plane, parachutes to earth

This 250 HP steel tractor-scraper-dozer can be flown in a C-130 aircraft and parachuted into a combat area, ready to operate. It can transport 10 cubic yards of earth at 35 mph. It owes its light weight and great structural strength to USS "T-1" Constructional Alloy Steel and USS MAN-TEN High Strength Steel. Three and a half tons of deadweight were saved by designing the yoke, dozer arms, front and rear axle housings and basic bowl structure with USS "T-1" Steel. MAN-TEN Steel is used in the bowl, side plates and dozer blade. The complete unit



is built tough and strong with 7,500 lbs. of USS "T-1" and MAN-TEN Steels. For other military vehicles, U. S. Steel makes extremely tough rolled armor plate, in addition to a complete line of weldable, formable high strength and alloy steels. For more information on any of these, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pa. USS, "T-1," PAR-TEN, and MAN-TEN are registered trademarks.

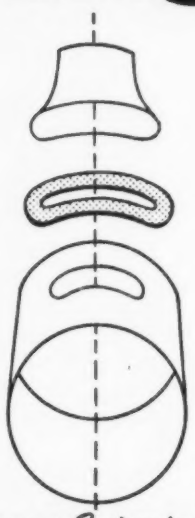
USS United States Steel

TRADEMARK

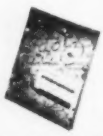
NEW CURVED
brazing
washers and shims

The operator no longer needs three hands to put the components together!

Applications on which one tube is radiused or saddled to fit over another are sometimes difficult to preform with a washer or shim. The stiffness of the washer may hold the radiused member away from the other tubes. By curving the washer to the curvature of the tube, the problem is minimized. Curving a shim permits snapping of the shim onto the tube.



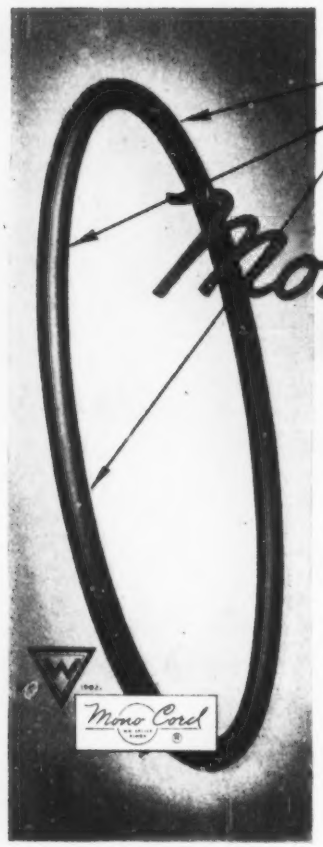
Write for FREE 20 page "PREFORM BRAZING HANDBOOK"



LUCAS-MILHAUPT *Engineering Co.*

5056 South Lake Drive, Cudahy, Wisconsin

CIRCLE 19 ON READER SERVICE CARD



NO SPLICE RINGS

Mono Cord one piece, no splice round section rings are used as reciprocating or static seals in pressurized systems by the automotive, plumbing and many other industries.

These seals, built to critical standards, must be leakproof against liquids or gases, unaffected by chemical or temperature changes and remain physically constant throughout use.

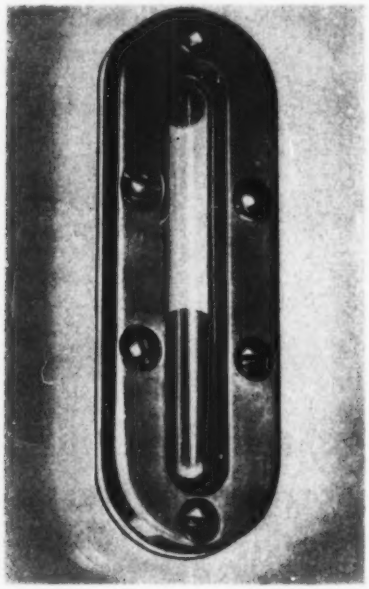
Mono Cord no splice rings are molded from natural and synthetic rubbers in a wide variety of sizes to fit your specifications. For precision rings at economy prices, specify Mono Cord rings by Western.

Write or phone for information, literature or a visit by our sales engineer in your area

WESTERN RUBBER CO.

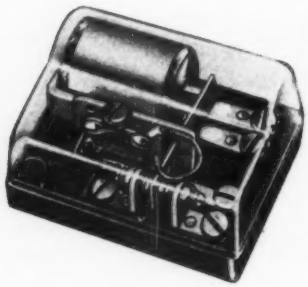
GOSHEN 10, INDIANA

Molded and Lathe-Cut Rubber Parts for All Industries



iations ranging from 1¾ through 5 in. Constructed of aluminum with clear plastic sight glass. **Technical Development Co, 305 S Chester Ave, Glenolden, Penna.**

Circle 315 on Reader Service Card



Plastic-encased relays . . . have factory-adjusted 5 milliw sensitivity with external adjustment screw for 4 to 50 milliw. Resistances of over 40,000 ohm are available. Contact arrangement is SPDT. **Elgin Advance Relays, 2435 N Naomi St, Burbank, Calif.**

Circle 316 on Reader Service Card

18-position rotary switch . . . has double ball detent indexing mechanism and an indexing plate that is said to assure positive operation even under extreme environmental conditions. Can be supplied with up to 15 decks per switch. Breakdown voltage rating is 1000 v rms with standard clips, 500 v rms with back-to-back insulating clips. Current rat-

continued, page 66

One Lamb FHP motor...up to 100,000 carbon copies mass-produced to exacting specifications

From a prototype . . . hundreds OR thousands of motors with absolute uniformity. Each and every motor produced has the same, discriminating, "built-in" perfection that you can expect with Lamb® manufacturing. This precise mechanical and dimensional uniformity of motor as an integral component for your powered product is extremely important . . . and Lamb makes sure you get it!

If you have a special motor problem . . . here's what you can expect from Lamb! *Into the design* of a Lamb motor goes years of experience in powering components for aircraft, domestic and industrial products. *Out of the design* comes a personalized motor that's dependable, smooth and efficient.

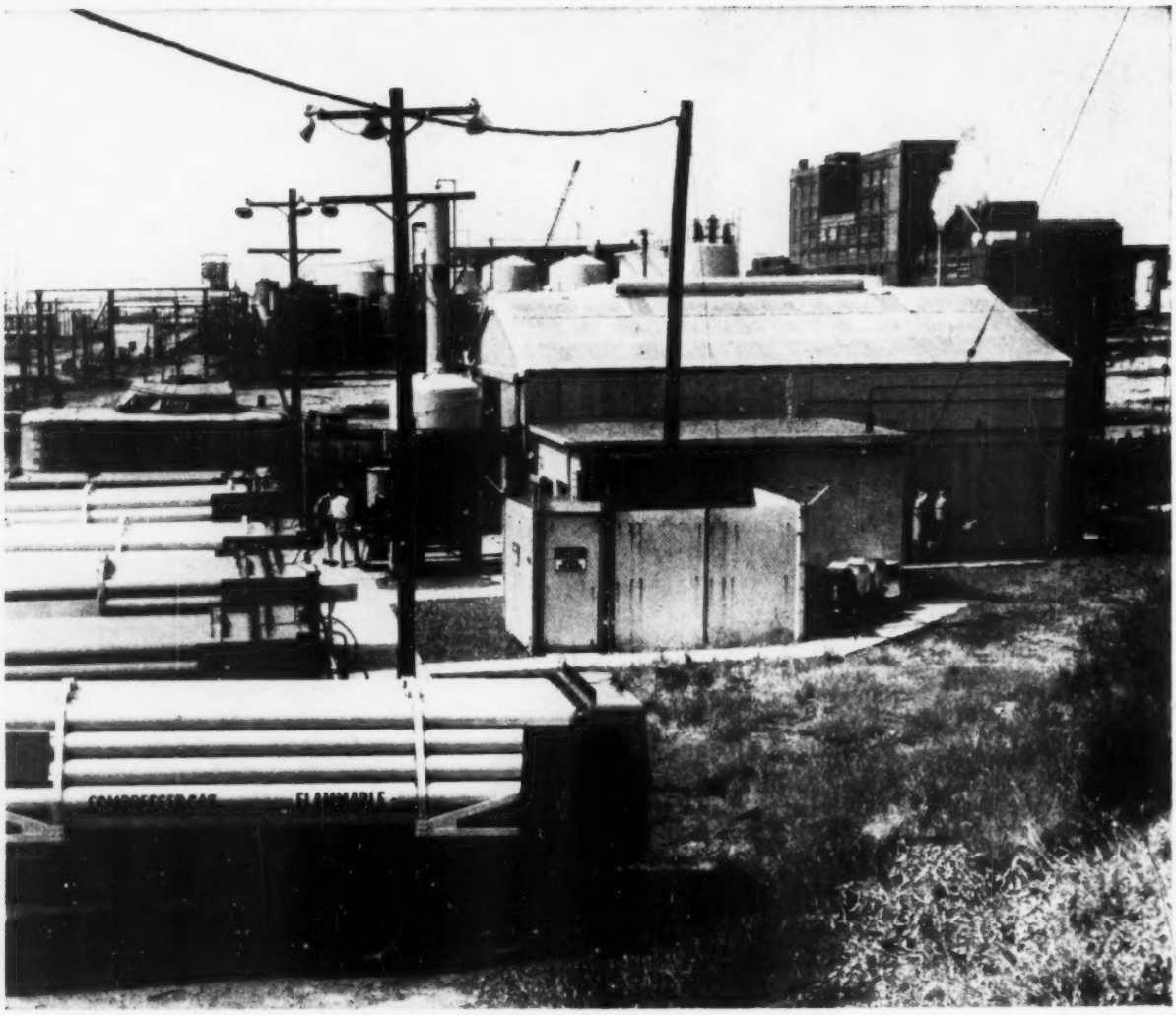
Cost-wise you're way ahead, because Lamb Motors are mass-produced at the most favorable cost.

Write today for descriptive folder. Or ask to have a District Engineer call and set up a personalized "Motor Conference".

AMETEK

LAMB ELECTRIC
A DIV. OF AMETEK, INC.
KENT, OHIO

CIRCLE 63 ON READER SERVICE CARD 63



How only 5 men and a small plant produce 15 million cubic feet of pure hydrogen a month

Nickel stainless steel permits unique plant design for new low-cost cryogenic process

What's so unusual about this Van de Mark hydrogen purification plant in Linden, New Jersey?

First, at a low capital investment of about $200,000, it has handled the purification of a neighboring refinery's off-gas hydrogen for 2½ years with no "downtime" and minimum maintenance. Only 5 men are needed to keep the plant going.

Second, the plant produces low-cost, pure hydrogen through a cryogenic process. Impurities are removed through fractional condensation when the hydrogen is cooled to −320 F. At this point, most other gases become liquid—yet the hydrogen remains a gas—permitting the liquids to be removed by means of absorbent beds and molecular sieves.

AISI Type 304 Nickel stainless steel was selected as the most practical and economical material for the absorbers, molecular sieves, and interconnecting piping. Strong and tough even far below −320 F, these Nickel stainless steel components are sealed away out of view . . . and away from the maintenance that simply isn't needed.

Type 304 is just one of the Nickel-containing steels that can withstand the damaging effects of super-cold . . . and at the same time offer the strength, toughness, and corrosion resistance that protects the purity of many a process stream. Ready availability plus fabricability are an added advantage.

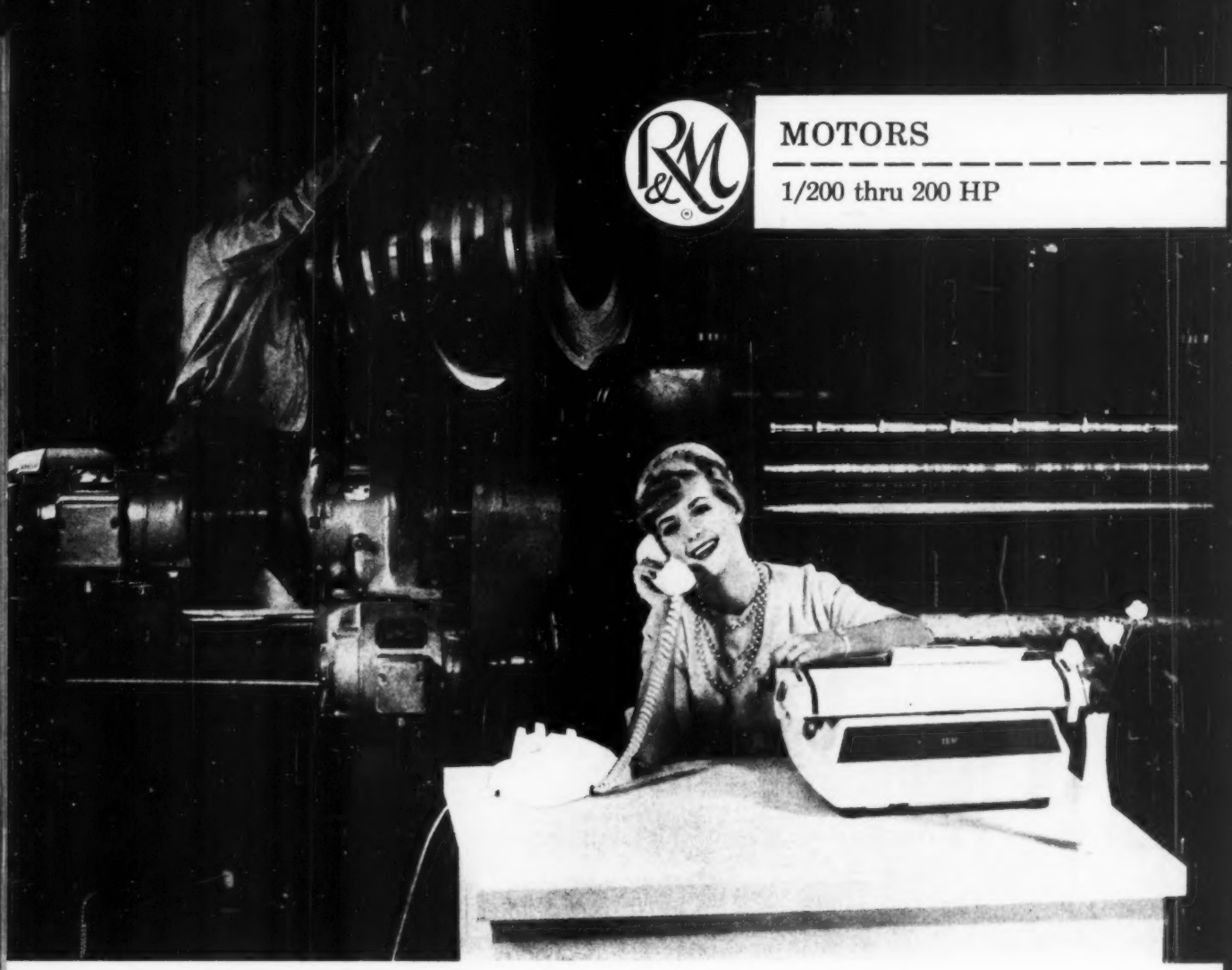
If your operations involve low temperatures (even −454 F) get the facts on how the Nickel-containing steels can go to work for you at practical cost. Write to Inco describing your metals requirements.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

MAKES STEELS PERFORM BETTER LONGER



MOTORS

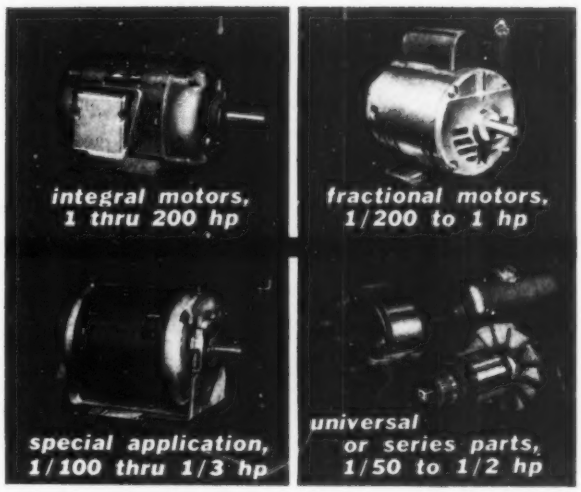
1/200 thru 200 HP

from machine tools to typewriters . . .

. . . Robbins & Myers motors power them all!

Each R&M motor, 1/200 through 200 HP, is electrically and mechanically designed with life-prolonging features which assure dependable operation, simplified installation and low maintenance. From rugged machine tools to complex business machines, there's an R&M motor for every job . . . Fractional and Integral H.P. Motors and Motor Parts in all popular mountings, electrical types and enclosures. Most are ready for off-the-shelf delivery. Others can be quickly produced. Should you require custom motors, R&M's experienced application engineers, aided by modern electronic computers, can furnish the one design best suited to your needs.

Write today for information, or send your powering problem to R&M. No obligation, of course!


integral motors, 1 thru 200 hp
fractional motors, 1/200 to 1 hp
special application, 1/100 thru 1/3 hp
universal or series parts, 1/50 to 1/2 hp

ROBBINS & MYERS, INC., Springfield, Ohio

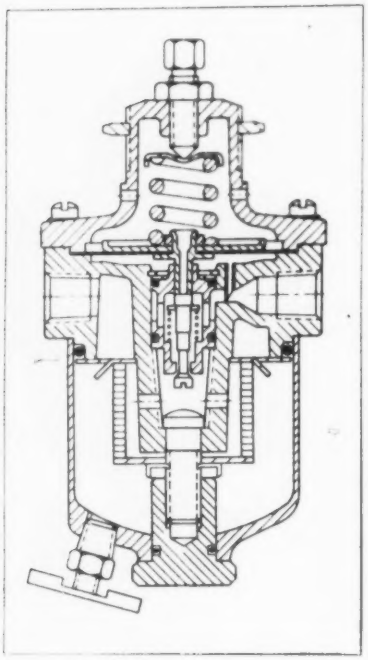
Fractional and Integral HP Electric Motors • Electric Hoists and Overhead Traveling Cranes • Moyno® Industrial Pumps Propellair® Industrial Fans • R & M-Hunter Fans and Electric Heat • Trade-Wind Range Hoods and Ventilators

Subsidiary companies at: Memphis, Tenn., Pico Rivera, Calif., Brantford, Ontario.

CIRCLE 65 ON READER SERVICE CARD

ings for silver-plated brass contacts are 0.250 amp at 115 v ac, 5.5 amp at 6 v dc. Silver alloy contacts also available. Operating temperature range is —65 C to 85 C. **Centralab, Electronics Div of Globe-Union Inc, 900 E Keefe Ave, Milwaukee 1.**

Circle 317 on Reader Service Card



Regulator-filter for air lines . . . is of the reducing-relief type and is available in 0-25, 0-60 or 0-125 psi pressure ranges, all with 300 psi inlet pressure rating. At 100 psi supply pressure full flow is 20 scfm. Filter will remove particles as small as 10 microns. **Conoflow Corp., 2100 Arch St, Philadelphia 3.**

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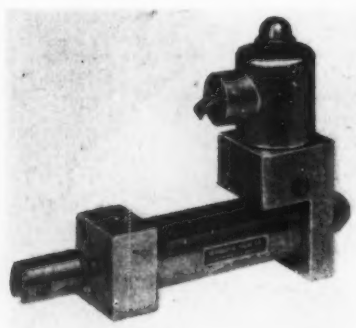

Valve-in-head single-acting cylinder of 1⅛-in. bore can be electrically or manually operated and is available with strokes of 1 to 4 in. Permits rear pivot mounting. **Automatic Valve Co, 37415 Grand River, Framington, Mich.**

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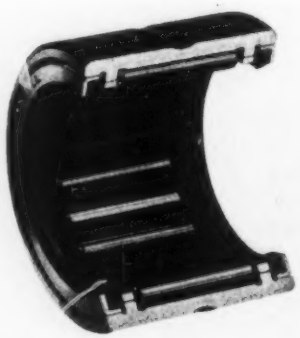


Cage-type roller bearings . . . are pre-lubricated and are made with integral seals and a retainer that controls roller alignment. Furnished with or without separable inner races. Dimensionally interchangeable with other needle bearings, these are available from stock in shaft sizes 0.625 in. up. **McGill Mfg Co Inc, Valparaiso, Ind.**

Circle 320 on Reader Service Card

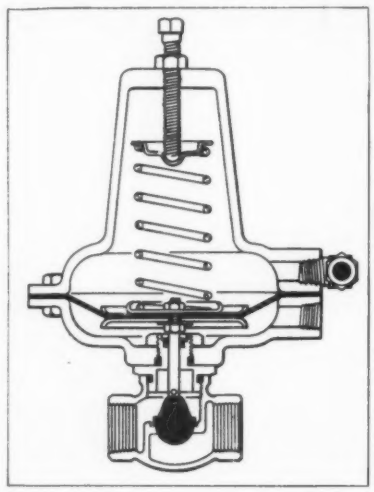
1500 psi hydraulic cylinder . . . was designed to provide shortest possible center-to-center pin distance. Available in 1½ to 3 in. bores, any strokes to 72 in. **Remco Hydraulics Inc, 934 S Main St, Willits, Calif.**

Circle 321 on Reader Service Card

Ultrasonic liquid level control . . . is explosionproof and has switch which is triggered by liquid touching probe surfaces, with repeatability said to be within thousands of an inch. Operates in any position and is not affected by foam, droplets or film buildup. Also operates independently of such fluid properties as dielectric, pressure, temperature, resistivity, conductivity. **Powerton Ultrasonics Corp, Expressway Industrial Park, Plainview, NY.**

Circle 322 on Reader Service Card

Diaphragm valve . . . originally designed for fuel handling can also take oil, gas, water, glycol, distillates in back pressure, regulator, thermostat, shut-off service. Has bronze body, stainless steel stem, Buna-N plug with nylon-reinforced Buna-N diaphragm in aluminum case.



For process temperatures to 250 F, pressures to 125 psi. Available in 1, ¾, ¼ in. pipe sizes. **Instruments Inc, Sub of National Tank Co, PO Box 556, Tulsa, Okla.**

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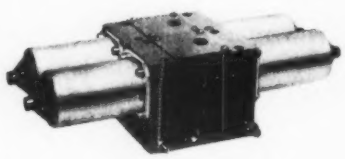

Four-way, 3000 psi solenoid valve for operation on dc and originally designed for service in mobile equipment hydraulic systems has subplate mounting that can be banked to simplify piping. All electrical wiring is enclosed. Available in ½ in. NPT with various spool designs. **Electro-Hydraulics Co, Inc, 134 W Grand Lake Blvd, W Chicago, Ill.**

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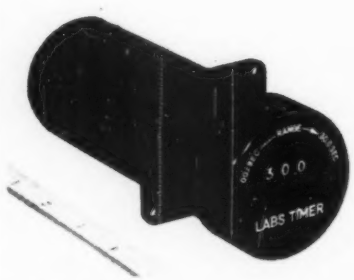


Digital timer . . . provides 0.1 sec increments, range of 0.00 to 30.0 sec and is accurate to ±1% of set time. Requires no

continued, page 79

The finish on this unit has

PRODUCTION and

DESIGN ADVANTAGES

for your products, too.

*Masland Duran Clad finish on air-conditioner by Carrier Corp. Finished laminate by Arvinyl Div., Arvin Industries, Inc., Columbus, Ind.

Masland Duran

CLAD

vinyl finish

This versatile vinyl-metal laminate enables you to work with prefinished parts . . . because it provides a built-in finish that can be cut, crimped, drilled or even deep-drawn during fabrication. Needs no new processing equipment. Often eliminates baking and spraying. Design effects in color and texture are limitless.

Industrial Products Division
THE MASLAND DURALEATHER CO.
Dept. PE, Philadelphia 34, Pa.
PLANTS:
Philadelphia, Pa. • Mocksville, N. C.

The Masland Duraleather Co., Dept. PE-L
Amber & Willard Streets, Phila., 34, Pa.
Send information and samples of Clad.

Name_____

Title_____

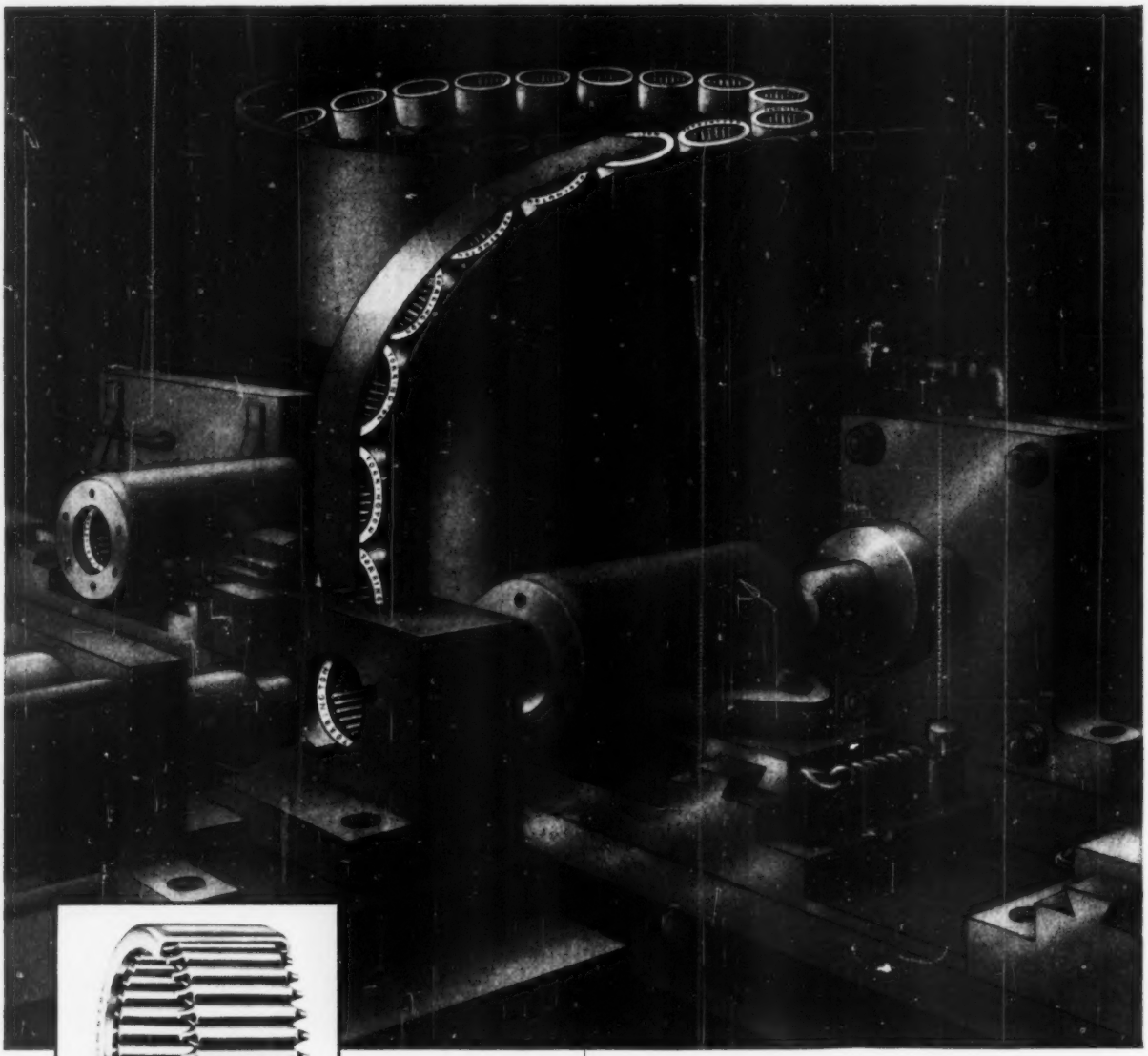
Company_____

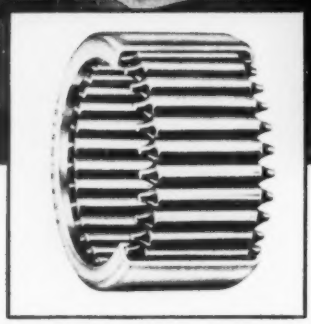
Street_____

City_____

Zone_____ State_____

CIRCLE 67 ON READER SERVICE CARD





TORRINGTON NEEDLE BEARINGS FEATURE:

- ☐ Unique unit construction
- ☐ Full complement of retained rollers
- ☐ Unequalled radial-load capacity
- ☐ Low coefficient of starting and running friction
- ☐ Low unit cost
- ☐ Long service life
- ☐ Compactness and light weight
- ☐ Run directly on hardened shafts
- ☐ Permit use of larger and stiffer shafts

It's easy as 1–2–3 with . . .

LOW-COST TORRINGTON NEEDLE BEARINGS! They can be installed easier and faster than any other type of anti-friction bearing. There's no waste time . . . no waste motion. No collars, shoulders or retaining rings to complicate assembly. Just one quick ram stroke . . . and the Torrington Needle Bearing is completely and firmly installed.

These exceptionally low-unit-cost and assembly advantages are yours whether you're geared for large volume, high-speed runs on automated machines . . . or lower volume, lower-speed assembly on simple arbor presses. Either way, you'll find it pays to specify Torrington Needle Bearings.

Torrington Needle Bearings offer other outstanding design and performance benefits. For details on how they can help you, call or write us today.

progress through precision **TORRINGTON BEARINGS**

THE TORRINGTON COMPANY Torrington, Conn. • South Bend 21, Indiana

CIRCLE 69 ON READER SERVICE CARD→

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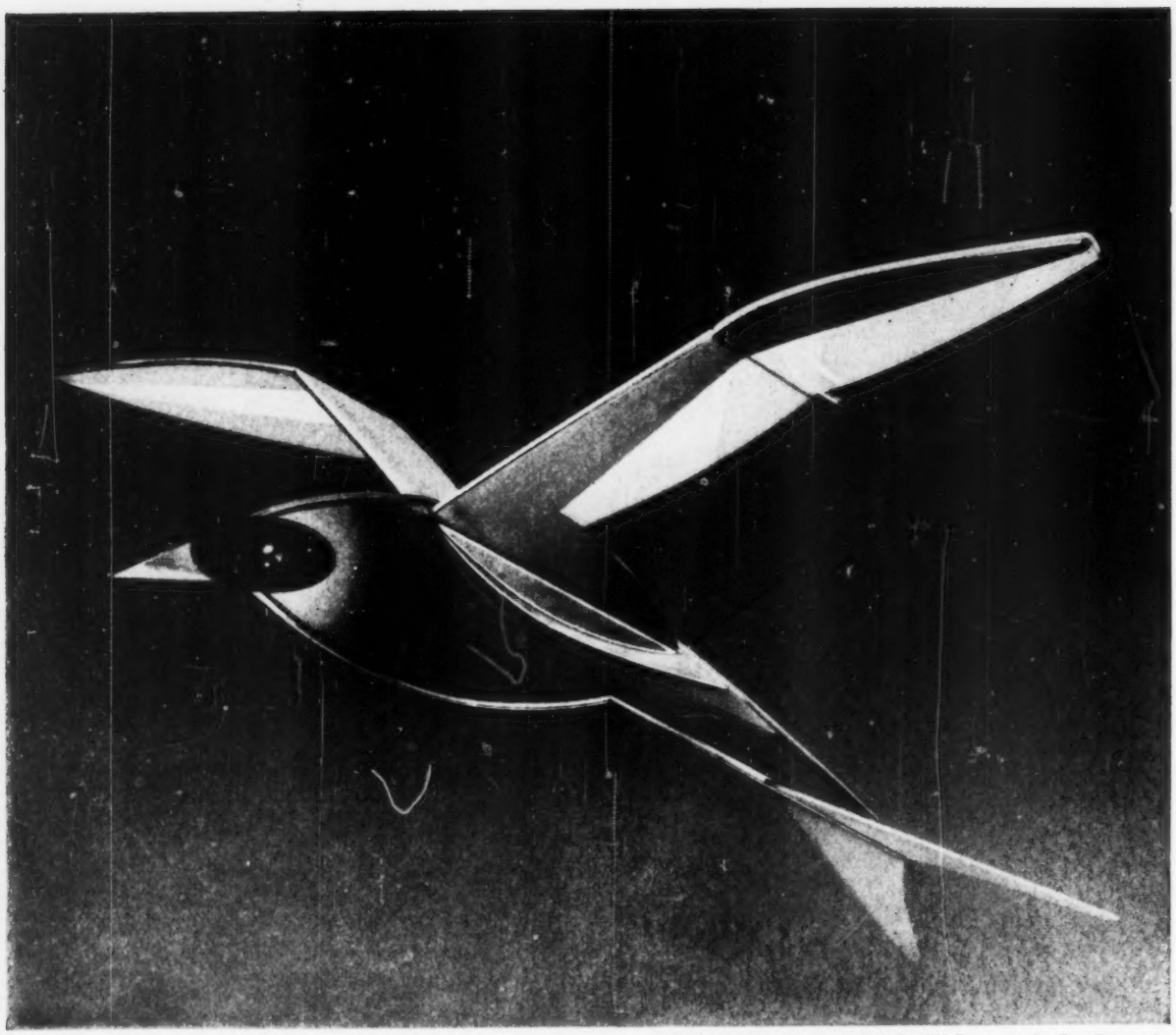

Sculpture created especially for 3M Company by Guy Palazzola

FEATHER-LIGHT...

3M Adhesives help take pounds off today's metalworking products

Reducing dead weight can give a product extra sales advantages . . . make it easier to handle and assemble . . . lower shipping and production costs. The answer: Fabricate with 3M Industrial Adhesives and save weight without sacrificing strength.

In fact, 3M Adhesives often substantially increase the strength of an assembly by distributing stresses evenly over a wide area, making lightweight, high-strength designs possible. And without mechanical fasteners that lower the integrity of the material and cause stress points that tear, fabricators can substitute lighter gauge materials.

For example, 3M Adhesive EC-1357—only one of a complete line of strong, general purpose industrial adhesives—finds wide application in products requiring strength and light weight. It is used in the bonding of metal frames to veneered plywood . . . in honeycomb construction for table tops . . . in sandwich-type wall panels, where it bonds porcelain enameled steel to an expanded glass core.

Backed by a quarter century of research, 3M Technical Service is solving fabrication problems for leading manufacturers in various industries. For an accurate appraisal of how an adhesive can add strength, light weight, production economy, and greater design freedom to your process or product, look first to 3M. Write AC&S Division, 3M Company, Department SBS-121, St. Paul 6, Minnesota.

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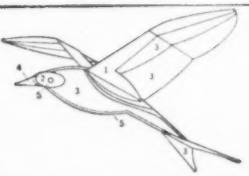

What do you want to bond to what?
The Bird is fabricated of these materials and bonded with a variety of 3M Adhesives:
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ADHESIVES, COATINGS AND SEALERS DIVISION

MINNESOTA MINING AND MANUFACTURING COMPANY

. . . WHERE RESEARCH IS THE KEY TO TOMORROW

3M COMPANY

Your turn

...to participate in the current problems of our profession.

Wiliam Griffel, PE and supervisory engineer at Picatinny Arsenal, Dover, NJ, is out to reduce everything to *K*-factors. He did it for constant-strength beams and for flat springs, and now has added **maximum deflection and maximum slope** of 16 more beams to his conquests. Of course, the purpose of figuring out *K*-factors is to shorten the equations and simplify the nomographs. Often they also make comparisons easier. For instance, from the equation for maximum deflection $y = WL^3/KEI$ one can see that maximum deflection is inversely proportional to *K*. By comparing values of *K* from the table it becomes clear that a simply supported beam with a uniform load will deflect 8/76.8 or 10.4% as much as a cantilever beam of the same length.

Both the equation above for deflection and the one for slope $\theta = yK_1/L$ hold true only up to the proportional limit, so it is a good idea to test whether or not stress is within this limit with the flexure equation $S = Mc/I$. The right hand column of the table gives max *M* for making the check.

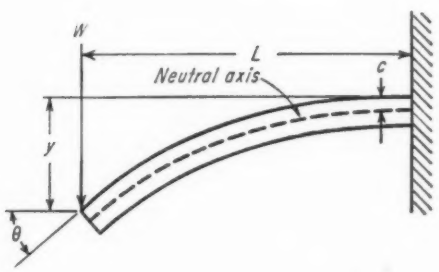
Another point to watch for is whether *E* for the metal you are using is different from *E* assumed in the nomograph, which is $E = 30 \times 10^6$ for steel. When using a different *E*, find true deflection by multiplying $y \times 30 \times 10^6/E$.

Let's try some numbers to see how the *K*-factors work. A steel cantilever beam is 10 ft long, 12 in. deep, and has a moment of inertia about the horizontal neutral axis of 215.8 in.^{4}. If it carries a 10,000 lb concentrated load at the end, what is maximum deflection and slope?

A cantilever with end load is Type 1 in the table where we find that $K = 3$. This completes the information necessary to draw the three lines on Nomograph I which find $y = 0.11$. Since the beam is steel, there is no need to correct the answer for a different *E*.

Knowing deflection we can now solve for slope with Nomograph II. After looking up $K_1 = 1.50$ in the table, draw two lines to find $\theta = 0.0027$. Note that the answer is in radians. This is because at the small angles met in practice the tangent is almost the same numerically as the angle expressed in radians.

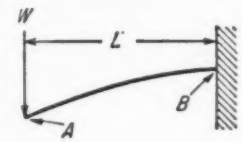
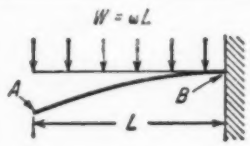
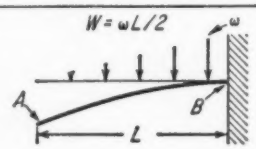
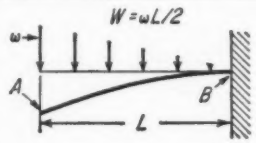
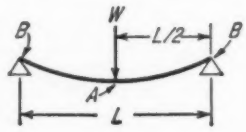
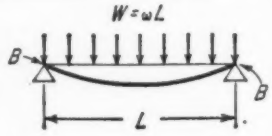
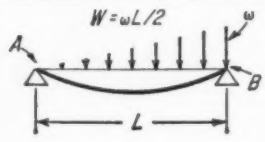
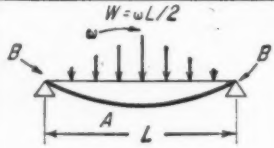
As a final precaution make sure that the steel beam is not stressed above its proportional limit of 30,000 psi. Max $M = WL$ from the table; c = depth/2 = 6 for this symmetrical beam. Thus $S = Mc/I = WLc/I = 10^4 \times 5 \times 12 \times 6/215.8 = 16{,}680$ psi, so the answers are valid.

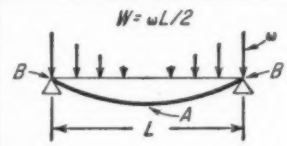
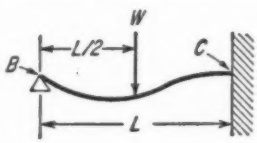
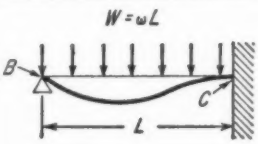
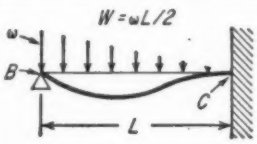
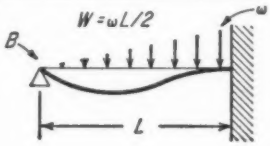
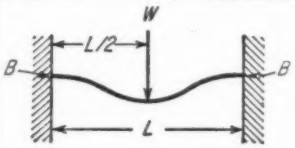
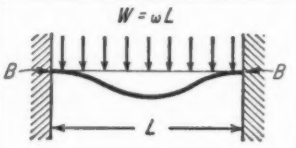
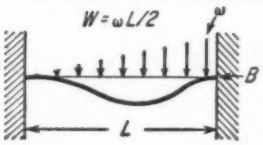


SYMBOLS

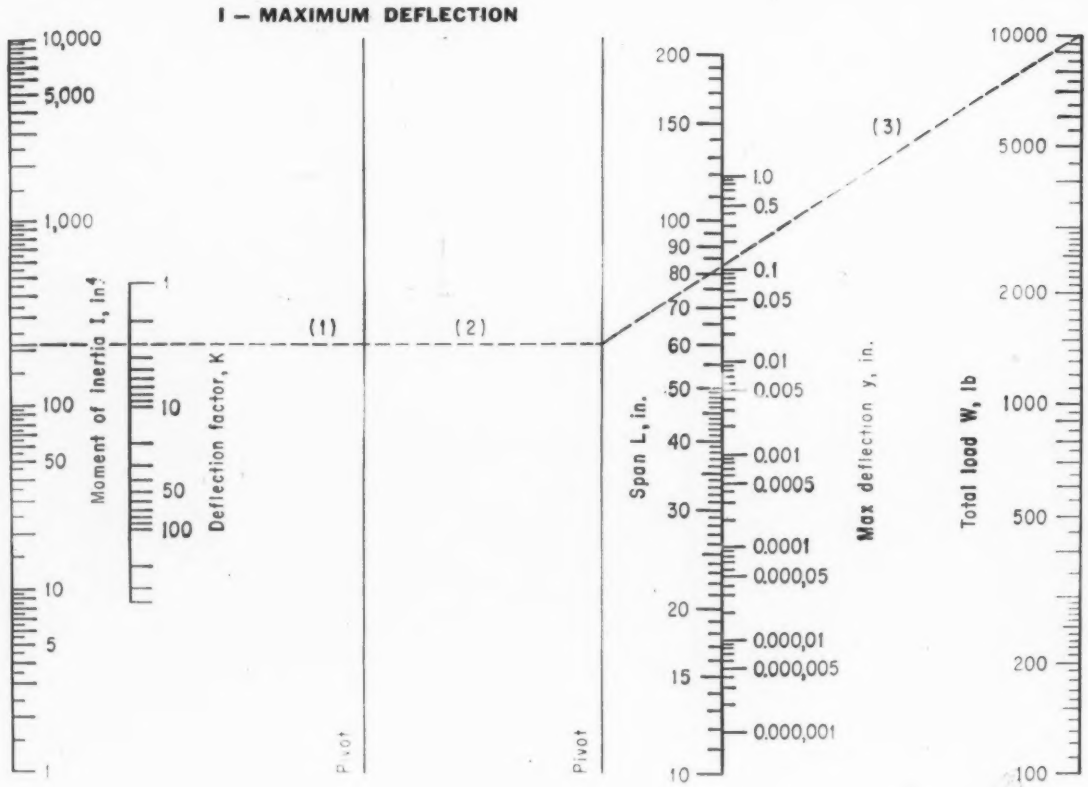
- c = distance of extreme fiber from neutral axis, in.
- E = modulus of elasticity, psi
- I = moment of inertia of the cross-section of the beam, in.^{4}
- K = deflection factor
- K_1 = slope factor
- L = span, in.
- M = max bending moment, lb-in.
- S = max allowable bending stress, psi
- W = total load, lb
- y = deflection, in.
- ω = greatest unit value of a distributed load, lb/in.
- θ = slope, rad

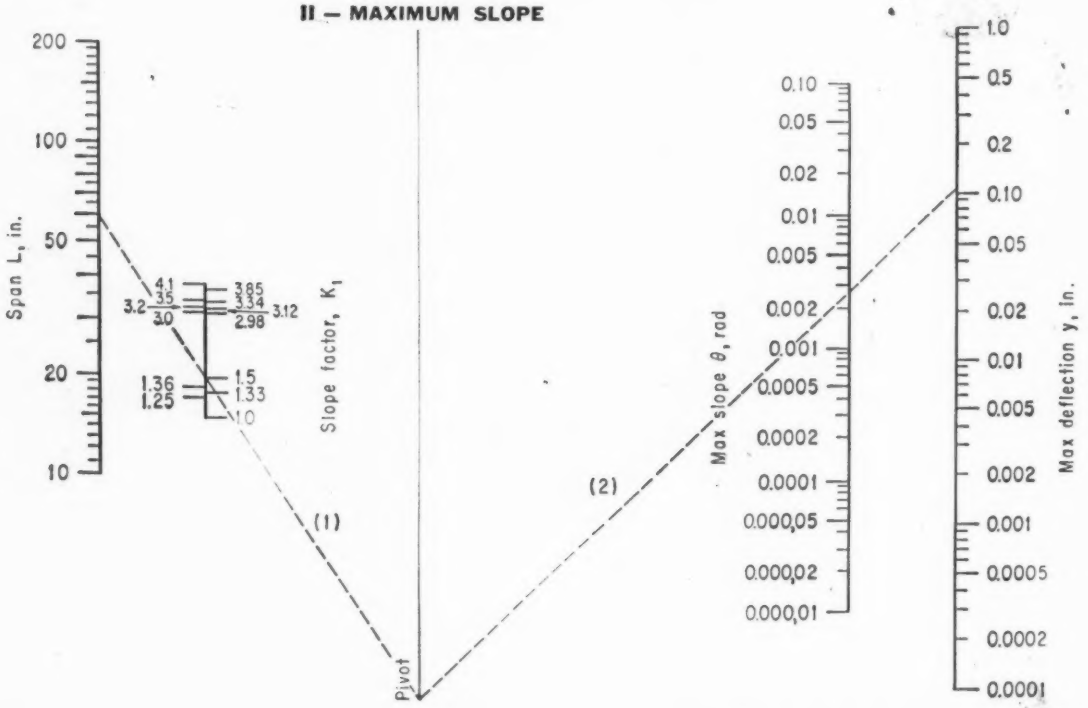
YOUR TURN *continued*

	Beam Type	K for deflection	K_1 for slope	Max M
1		3 at A	1.50 at A	WL at B
2		8 at A	1.33 at A	WL/2 at B
3		15 at A	1.36 at A	WL/3 at B
4		5.45 at A	1.36 at A	2WL at B
5		48 at A	3 at B	WL/4 at A
6		76.8 at L/2	3.20 at B	WL/8 at L/2
7		76.7	2.98 at A 3.41 at B	0.128 WL
8		60 at A	3.12 at B	WL/6 at A

	Beam Type	K for deflection	K_1 for slope	Max M
9		106.7 at A	3.33 at B	WL/2 at A
10		107.3	3.35 at B	3WL/16 at C
11		185	3.85 at B	WL/8 at C
12		164	4.1 at B	7WL/60 at C
13		210	3.50 at B	2WL/15
14		192 at L/2	—	WL/8 at A,B
15		384 at L/2	—	WL/12 at B
16		382	—	WL/10 at B

YOUR TURN *continued*





Linde materials & coatings News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Polish semiconductors scratch-free with 99.98% pure alumina powders

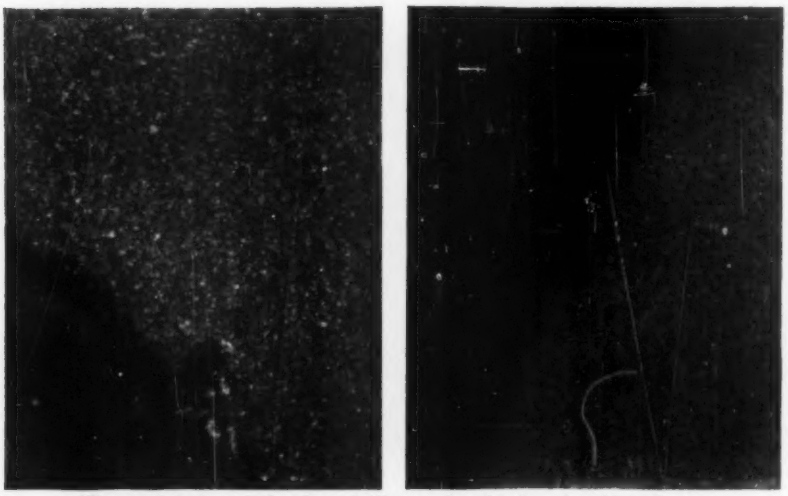


Photo at left: A typical as lapped silicon wafer, showing edge chip, prior to finishing. *(Magnified 42X).* **Right:** Complete polishing with LINDE alumina abrasives leaves edge of silicon and wafer scratch-free. *(Magnified 144X).*

The surfaces of the semiconducting wafers used in the new high-speed mesa switching transistors and planar diodes must have a superior surface finish, flatness, and parallelism—prior to final etching and diffusion. This effect is now being achieved in full production with high-purity alumina abrasives produced by LINDE.

Three particle sizes

Three basic particle size ranges of aluminum oxide powders suitable for polishing silicon and germanium wafers are available for this application, as well as many others. The difference in size and hardness, as listed below, give these 99.98% pure powders their individual properties.

	TYPE 0.3A	TYPE 0.05B	TYPE 1.0C
Formula	Al_2O_3 (Alpha)	Al_2O_3 (Gamma)	Al_2O_3 (Alpha)
Crystal System	Hex.	Cubic	Hex.
Hardness, MOHS'	9	8	9
Size, Microns	0.3	0.05	1.0

Type 1.0C is used to remove stock from surfaces that are rougher than 6 microinches rms; Type 0.3A for preliminary polishing, and Type 0.05B for final polishing of the wafers.

In the initial stages of junction transistor or diode production, the powders can be used for preparing metallographic cross-sections of the assemblies according to standard methods on a horizontal polishing wheel. For semiconductors, LINDE has developed several adaptations of standard techniques.

Extremely uniform

LINDE Types A, B, and C alumina powders are chemically prepared and have an extremely uniform ultimate particle size which obviates any further levigation before use. By simple reference to a specific lot number, succeeding production lots can be ordered with abrasive properties tailored to an individual application.

For data on semiconductor and other critical polishing, check the coupon.

Flame-Plated tungsten carbide coatings precision-finished

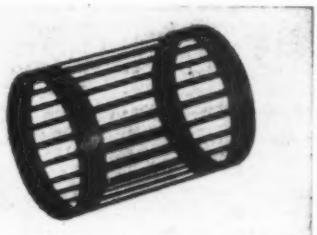
Tungsten carbide coatings, applied with the LINDE Flame-Plating process, are being used successfully on hundreds of precision parts because the coatings are well suited for finishing down to 1 microinch rms.

Most frequently used precision grinding equipment is diamond wheels, resulting in lowest overall cost on ordinary cylindrical and flat work. On many contour grinding jobs, special grades of silicon carbide wheels will do the job, eliminating the high cost and lack of precision associated with shaped diamond wheels. Diamond-abrasive lapping techniques give high finishes.

Get complete data on Flame-Plating precision parts—send the coupon.

Plasma-Plate process applies thin dielectric coatings

Next time you need a low-cost, thin dielectric coating for cathode cups, consult Linde Company. LINDE's Plasma-Plate process has economically put alumina insulation coatings on molybdenum cups, and has even built structures on mandrels—for example, the grid cage shown below. This inert gas process can apply refractory metals melting up to 7100° C., also metal carbides, borides, and oxides, to a variety of base metals. Discuss your requirements with us. For further information, check and send the coupon.



Tungsten grid cage—intricate structure built up on mandrel using the Plasma-Plate process.

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Technical-ities

by Fred E. Graves

Nuts have performance 'designed in'

A standard nut isn't as simple as it looks. Much design know-how goes into its manufacture. Proper design avoids these pitfalls.

1. Thread shear: Several factors cause this. The nut may not be high enough to contain sufficient threads; its material may lack plasticity that enables it to deform under tightening so that enough threads engage and distribute the load to avoid progressive shear.

2. Wall dilation: The inclined-plane effect of the thread's helix angle resolves torque on a nut into two components: vertical (shear) and horizontal (dilation). Dilation enlarges nut's diameter, shifting the load towards weaker *tips* of threads.

3. Crushing: Nuts that aren't wide enough across the flats bear down on too small a surface. High unit stress may crush the bearing surface, with relaxation of bolt tension the undesirable end result.

Reputable fastener manufacturers provide you with ASA "Finished" nuts having enough height to sustain high thread tension, sufficient wall thickness to control nut dilation under load, and the right amount of bearing area. Nuts manufactured for ASA's "Heavy" series are higher and $\frac{1}{8}$-inch wider across flats for added bearing area and wall thickness. They are generally used with high strength bolts or when bolt holes have large clearances.

Sintered nuts are so strong bolts fail before they do!

IN A brute force test of strength, sintered stainless-steel nuts and cold-headed standard hex screws were assembled and pulled apart in a tensile tester to determine what would fail first.

Results you see pictured above—$\frac{1}{2}$ inch hex bolts, stretched to failure. But their sintered nuts show no damage, either to internal threads or wall.

QUALITY GOVERNS STRENGTH

What gives sintered products their strength? At RB&W it's strict attention to purity of raw metal powders plus carefully-controlled mixing, compacting, and sintering. Also special heat treatments.

The table shows typical proof loads achieved by RB&W sintered nuts. They're more than ample for the bolts. Full size range available.

Size	Material	Proof Load (lbs.)
¼-20	*Brass	2060
¼-20	**18-8 Stainless Steel	3800
⅜-16	*Brass	5000
⅜-16	**18-8 Stainless Steel	9300
½-13	*Brass	9200
½-13	**18-8 Stainless Steel	17050

*Equivalent to screw stress of 65,000 psi
**Equivalent to screw stress of 120,000 psi

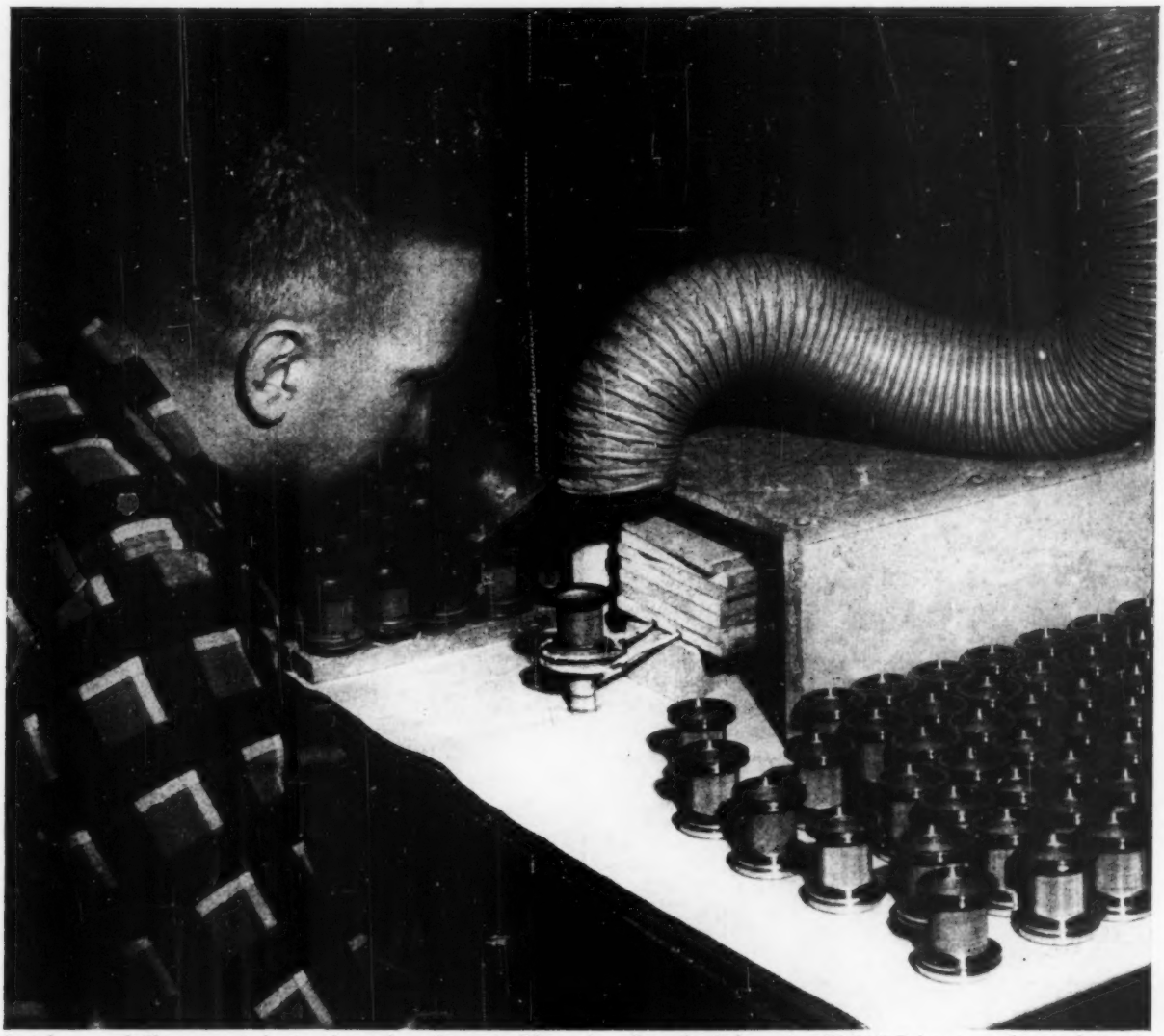
OTHER PHYSICAL ADVANTAGES

These nuts have excellent surface finish. Holes are perfectly round; threads are thus precisely tapped.

Perfectly dimensioned, corners filled out, chamfers uniform—each sintered nut is an exact reproduction of the other.

The same quality workmanship and facilities which fashion RB&W's stainless steel and brass sintered nuts are also at your service for sintering special parts. Write Russell, Burdsall & Ward Bolt and Nut Company, Port Chester, N. Y.

Plants at: Port Chester, N. Y.; Coraopolis, Pa.; Rock Falls, Ill.; Los Angeles, Calif. Sales office and warehouse at: San Francisco, Calif. Additional sales offices at: Ardmore (Phila.), Pa.; Pittsburgh; Detroit; Chicago.



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SILVER BRAZING—the precise tool for precision fabricating

The ability of silver brazing to serve fabricators literally through thick and thin is well illustrated by the experience of Dynamic Filters, Inc.

This firm manufactures fine filters for industrial, aircraft, missile, nuclear and marine use by bonding woven wire cloth of desired mesh to a coarser backing screen, forming and joining to required shape and attaching necessary fittings.

Since the filters must be capable of screening out particles ranging down to 2 microns in size, often under heavy pressure, any flaws in joint material or method would naturally be fatal. Dynamic Filters gets complete joint reliability by silver brazing with Handy & Harman EASY-FLO brazing alloys and Handy Flux. How do they know? They inspect all joints 100%.

Equally decisive in their choice of silver brazing is its compatibility with both the relatively thick fittings and thin wire mesh. EASY-FLO melts quickly at relatively low temperatures so metal is not annealed, oxidized or otherwise damaged, forms a thin, molten metal film that penetrates into small voids and capillary spaces, then solidifies to form strong, neat joints requiring little or no finishing.

Add to this the advantages of volume production at often negligible expenditure in brazing materials and you'll see why silver brazing is becoming more and more the favored method for beating fabrication costs. Get complete information—send for a copy of our data-packed Bulletin 20. It's yours for the asking. Write today.

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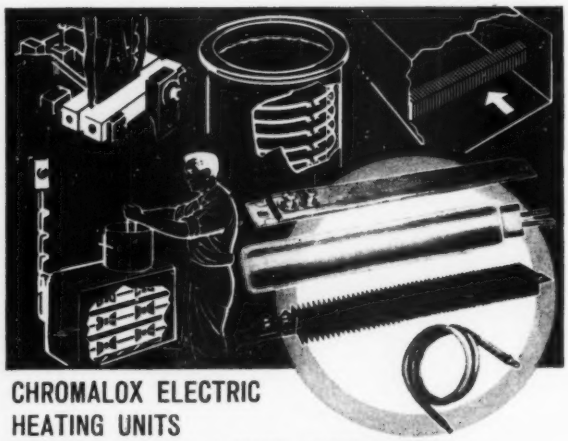

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warmup and resets automatically, with two switching functions capable of 5 amp resistive loads. For −55 C to 71 C, governed dc motor draws 18 w at 27 v dc. Weighs less than 2 lb and is 6.205 x 2.265 in. dia, except for turning knob. **Globe Industries Inc, 1784 Stanley Ave, Dayton 4, Ohio.**

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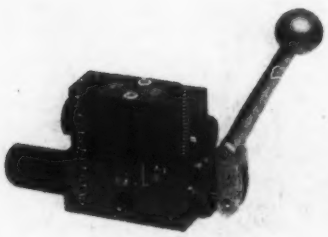

Lever-operated four-way valve . . . for use with hydraulic oils and other non-corrosive fluids at pressures up to 3000 psi, weighs 18 oz and is available in 12 portings for foot, subplate and tandem mounting. Also suitable for banking in series or parallel. For ¼ in. pipe. **Sarasota Precision Products Inc, 5757 McIntosh Road, Sarasota, Fla.**

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Smaller power supply . . . has output of 70 w, 35 v, 2 amp, at claimed effiiciency of 85%. Total volume is 80 cu in., weight 6½ lb. Regardless of load, internal dissipation is 12 w max and regulation is 0.02% against line or load. **Power Devices Inc, 8710 Derby Ave, Northridge, Calif.**

Circle 327 on Reader Service Card

Gearhead motor . . . of synchronous-hysteresis design can be furnished with two, four or eight poles for speeds of 3600, 1800 or 900 rpm, respectively. Max current is 1 amp, Input can be single or double-phase, 115 v, ac, 60 cps. Typical unit is 5.5 in. long, weighs 4 lb 10 oz. **Globe Industries Inc, 1784 Stanley Ave, Dayton 4, Ohio.**

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Flangeless silicon rectifier . . . is available in five types for 150, 175 and 200 C operation, 850 and 600 milliam. Also available for applications requiring to 1000 v. **Semicon Inc, Sweetwater Ave, PO Box 328, Bedford, Mass.**

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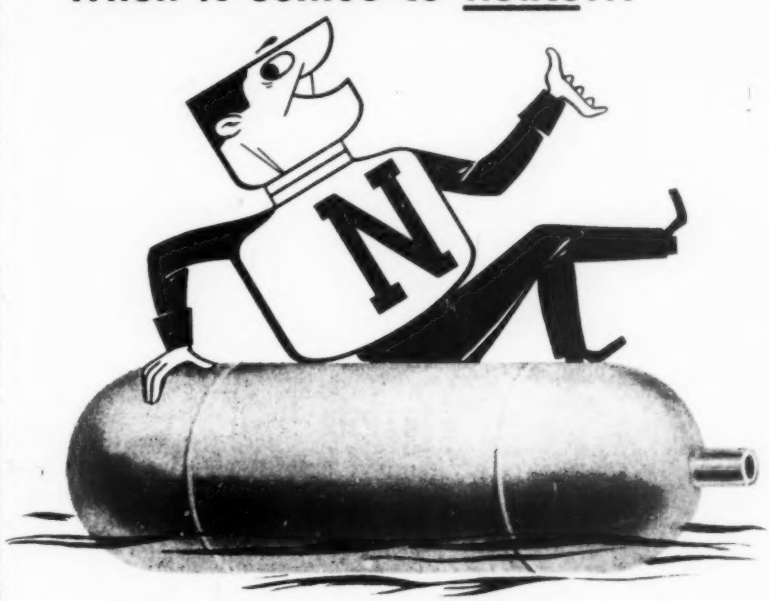

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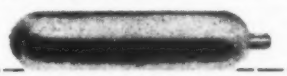

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DESIGN LITERATURE

Magnetic control of industrial motors

GERHART W. HEUMANN, John Wiley & Sons, Inc, 440 Park Ave S, New York 16. 6¼ x 9¼; Part I-272 pp, Part II-334 pp. $9 each.

These two books (and a third which will follow soon) are an excellent roundup of all the controls and accessories important to motor control. Many of the devices—relays, rheostats, solenoids, brakes—are just as applicable to other controls such as linear and rotary power actuators. Theory and derivations are avoided, but careful descriptions are given of every important function and device. Symbols and diagrams are introduced first, and logic functions are covered in a later chapter. The controllers and motors are discussed together in separate, unified chapters, which makes it handier for reference. Here are typical chapter headings. Part I (ac control devices): ac contactors and relays, accessories, control-circuit devices, resistors, rheostats, solenoids, thrustors, brakes, mechanical design of controllers, maintenance. Part II (ac motor controllers): drive characteristics, squirrel-cage motors, wound-rotor, synchronous, logic functions and static devices, motor protection, branch protection. Part III (dc motor controllers) has not been published yet, but will cover all variable-speed drives using dc motors.

The author is chairman of the ASA Sectional Committee C19 on industrial control equipment, and he participates actively in work of the International Electrotechnical Commission, having served as Chief US delegate on control gear at a number of its meetings. He is also advisor on control gear to the US National Committee of the IEC. *—FDY*

Increasing the loading on gearing and decreasing its weight

M M SAVERIN. Pergamon Press Ltd., 122 E 55th St, NY 22. 6¼ x 9¾, 204 pp. $12.00.

Of considerable importance in mechanical engineering is the possibility of reducing the weight of machines while simultaneously improving their performances.

This important volume contains the results of a series of investigations in the USSR undertaken to find the most efficient ways of running gear transmissions to allow full use of their load-carrying capacity and to reduce their weight.

The book includes articles on the performance of a number of reduction gears presently in use in several rolling mills, measures to reduce the weight of cylindrical reduction gears, investigations into the laws governing changes in the life and fatigue limit of tooth surfaces as a function of loading conditions, results of investigations on the load-carrying capacity of gears with extended center-distance meshing with zero total displacement of the original contour, investigations of the load-carrying capacity of gears with extended center distance meshing with a large positive total displacement, the problems of the dynamics of spur gears and the experimental determination of the rigidity of gear teeth.

Other books of interest

Fuel Cells and Related Research

SB-447. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8 x 10½, 7 pp. 10¢

A partial bibliography containing reports of work period 1945-60.

Human Performance as a Function of the Work-rest Cycle

PB 161958. O S Adams, W D Chiles. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8½ x 11, 18 pp. 75¢

High Temperature Metallurgy and Heat Resistant Alloys

SB-452. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8 x 10½, 35 pp. 10¢

A bibliography including reports from period 1950-Feb 1961.

Heat Treatment of Metals

SB-454. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8 x 10½, 19 pp. 10¢

A bibliography including reports from period 1942-60.

Research on the Effects of Isolation on Cognitive Functioning

PB 161922. R R Holt, L Goldberger. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8½ x 11, 22 pp. 75¢

Analytical and Experimental Study of a Method for Literature Search in Abstracting Journals

PB 17178. A O Cezairliyan, P S Lykoudis, Y S Toukoukian. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8½ x 11, 69 pp. $2

Review of Some Unconventional Methods of Machining

PB 161225. Battelle Memorial Institute. Office of Technical Services, US Dept of Commerce, Washington 25, DC. 8½ x 11, 22 pp.

1961 SAE Handbook

Society of Automotive Engineers Inc., 485 Lexington Ave, NY 17. 8½ x 11, 914 pp.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover. For those catalogs and bulletins available only when requested on company letterhead, see page 85.

LIMIT SWITCHES—Booklet LJ-48, 20 pp. Reviews oiltight limit switches —rotary lever, wobble stick, rod actuators, and push-type operators, giving ratings, dimensions, operating data and mounting variations. Includes basic specification chart and typical applications. Cutler-Hammer Inc, 296 N 12th St, Milwaukee 1.

Circle 335 on Reader Service Card

BRAIDED AND TWISTED PACKINGS—Brochure AD-191, 20 pp. Details 70 standard packings, describing type of construction, materials used, and operating features. Offers application and installation data, packaging tables, and recommendation chart covering most widely used products. Also discusses molded asbestos valve rings and lubricating materials. Garlock Inc, Palmyra, NY.

Circle 336 on Reader Service Card

SOLENOID COMPONENTS—Condensed catalog, 6 pp. Provides detailed specifications and performance characteristics of over 70 different types of linear solenoids, rotary solenoids and electromagnetic devices. Covers ac and dc units and lists electrical and mechanical characteristics of solenoids from ⅜ in. to 2½ in. IMC Magnetics Corp, W Div, 6058 Walker Ave, Maywood, Calif.

Circle 337 on Reader Service Card

REINFORCED PLASTICS—Bulletin, 4 pp. Reviews cost, weight-vs-strength and other design considerations of molded polyester-glass, and also discusses applications. Contains list of mechanical, electrical and physical properties. National Vulcanized Fibre Co, 1061 Beech St, Wilmington 99, Del, or National Fibre Co of Canada Ltd, 107 Atlantic Ave, Toronto, Ont.

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MINIATURE & INSTRUMENT BEARNGS—Data sheet M-3, 2 pp. Covers 40 sizes, open and shielded, flanged and unflanged, including standard and narow width types, and extra-large OD bearings for synchros. Gives boundary, flange, land and

continued, page 83

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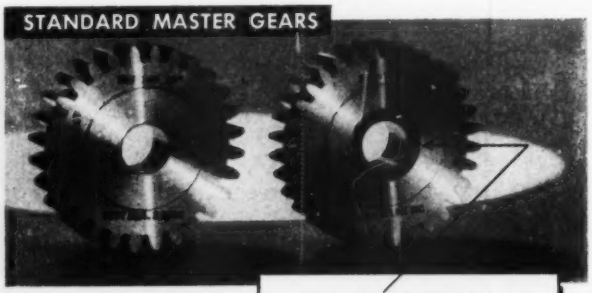

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undercut dimensions, as well as static and dynamic ratings, running torque values, radial play ranges, lubricants, retainer types, a nomenclature guide and tolerances. Barden Corp, 200 Park Ave, Danbury, Conn.

Circle 339 on Reader Service Card

COPPER-SULFUL ALLOY—Booklet, 18 pp. Gives properties, performance and application data on this high-conductivity, free-machining alloy. Contains a machinability report, summarizing results of tests, which discusses tooling information. Engineering drawings indicating tool geometry, and tables of feeds, speeds, and drill backouts are offered. Amco Sales Div, American Metal Climax Inc, New York 20.

Circle 340 on Reader Service Card

MOTORS, TACHOMETERS & SYNCHROS—Technical catalog No. 1, 60 pp. Details theory, performance, application, construction, testing and operating characteristics of high inherent damping, viscous damped, inertial damped, and standard synchronous motors, precision tachometers, rate tachometers, and all types of high-performance synchros and resolvers. Diagrams, equations and specification charts are offered. Kearfott Div, General Precision Inc, Little Falls, NJ.

Circle 341 on Reader Service Card

FRAME MOTORS—Booklet GEA-7308, 6 pp. Discusses features and advantages of all-angle 11-frame (4-in. diameter) and 21-frame (5-in. diameter) motors, rated 0.015 to 0.1 hp. Contains data on applications, ratings, performance, modifications, dimensions and motor accessories. General Electric Co, Schenectady 5, NY.

Circle 342 on Reader Service Card

CONTACT RELAYS—Catalog, 8 pp. Describes design details of mercury-wetted contact relays, giving electrical and physical performance characteristics, and including formulas to calculate contact-operating features. Reviews technical and application data, resistance ratings and maximum voltage values, and offers wiring diagrams. Potter & Brumfield, Div American Machine & Foundry Co, Princeton, Ind.

Circle 343 on Reader Service Card

PNEUMATIC RELAYS—Spec Sheet 451.24, 2 pp. Discusses function and operation, providing a schematic drawing of operating cycle. Also lists specifications, and includes an outline drawing of pneumatic limiting relay. Republic Div, Rockwell Mfg Co of Canada Ltd, Guelph, Ont.

Circle 344 on Reader Service Card

MAGNETIC STARTER — Bulletin 14-B3, 4 pp. Reviews size 3 magnetic starter, giving horsepower ratings, dimensions and electro-magnet data. Contains conversion information, and discusses design features including dual voltage, 110/220 or 220/440 v, coils which are also dual frequency, 50-60 cps. Offers dimension drawings. Furnas Electric Co, 1050 McKee St, Batavia, Ill.

Circle 345 on Reader Service Card

TESTING & TEST EQUIPMENT—Publication, 46 pp. Details tests applied to synchros, resolvers, servo motors, servo motor generators, gyros, and accelerometers. Presents theory, procedures, and equipment involved in performance testing. Transformation ratio, phase-shift, and electrical error tests are among diagrams offered. Kearfott Div, General Precision Inc, Little Falls, NJ.

Circle 346 on Reader Service Card

SILICON RECTIFIERS — Bulletin S-100, S-101, S-102, S-103, S-104, 2 pp each. Details five miniature devices, giving design and performance features, dimensions, ratings, voltage and environmental specifications. Semicon Inc, 200 Sweetwater Ave, Bedford, Mass.

Circle 347 on Reader Service Card

PRODUCT DEVELOPMENT SERVICES—Brochure, 16 pp. Describes and illustrates feasibility studies, design and engineering, fabrication, assembly and testing of models, and preproduction prototypes. Reviews standard and automatic shift transmissions, special gears and power equipment, etc., and outlines capabilities in mechanical, metallurgical, electrical and electronic engineering. Jered Industries Inc, 1300 S Coolidge Rd, Birmingham, Mich.

Circle 348 on Reader Service Card

BRONZE ALLOYS—Data sheet G-64. Reviews high-strength, extruded-manganese-bronze bearing alloys, giving chemical compositions, physical properties, descriptions and advantages, and typical applications. Also lists ASM, ASTM and government specifications. Ampco Metal Inc, Box 2004, Milwaukee 1.

Circle 349 on Reader Service Card

ROTARY AIR PUMPS — Bulletin 9161, 6 pp. Covers three 4-vane air pumps, providing range of vacuum to 26 in. hg, pressure to 13 psig and volumes from 12 to 54 cfm. Includes performance curves based on hp and cfm, plus dimensional data. Leiman Bros Inc, 102 Christie St, Newark 5, NJ.

Circle 350 on Reader Service Card

SLIP RING ASSEMBLIES—Catalog SR-1, 11 pp. Covers design and application of slip ring units, showing dimensions, specifications and construction. Also provides physical and electrical properties for silver graphite brushes and contacts. Superior Carbon Prod Inc, 9115 George Ave, Cleveland 5.

Circle 351 on Reader Service Card

COAXIAL CONNECTORS—Catalog TPS, 8 pp. Provides technical data and standard specifications for plugs, jacks, receptacles, and adapters. Reviews design features, mechanical, electrical and environmental characteristics, and offers dimension drawings showing standard and semi-rigid cable assembly instructions. General RF Fittings Inc, 702 Beacon St, Boston 15, Mass.

Circle 352 on Reader Service Card

POLYURETHANE-COATED MAGNET WIRE—Bulletin MW-1003, 4 pp. Contains technical information including specifications, dimensions, and performance characteristics, along with physical and electrical property data. Also includes summaries of test results and specification data outlined in the form of charts. Hudson Wire Co, Magnet Wire Div, Winsted, Conn or Cassopolis, Mich.

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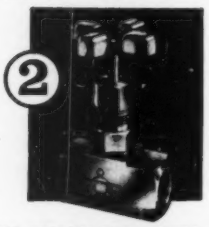

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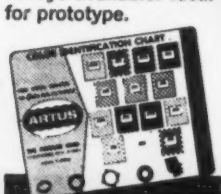

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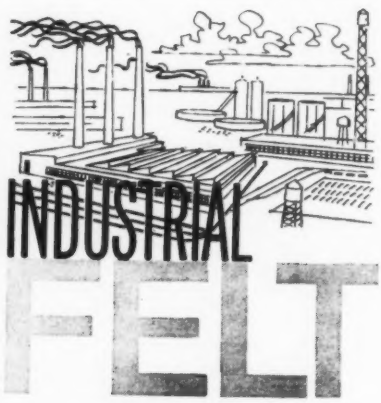

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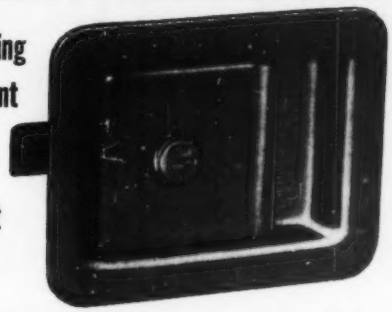

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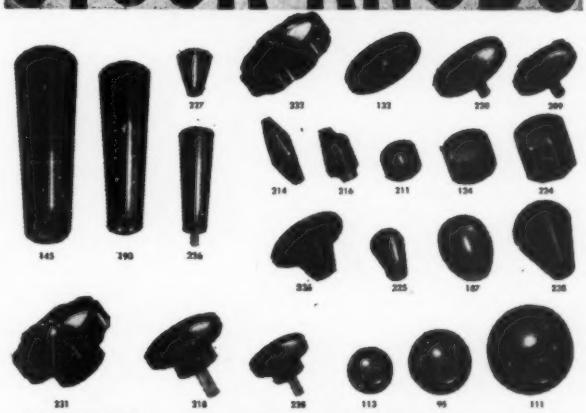

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INDEX TO ADVERTISERS

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American Lava Corp., Subs., Minnesota Mining & Mfg. Co 13
Artus Corp. 84

Chicago Rawhide Mfg. Co ..... 4th Cover
Continental Felt Co., Inc. 84

Dimco-Gray Co. 85
Doehler-Jarvis Div., National Lead Co 81
Driv-Lok Sales Corp. 78

Eastman Kodak Co., Recordak Corp., Subs 1
Eberhard Mfg. Co 85

Globe Industries, Inc. 12, 84
Grip Nut Co., Subs., Heli-Coil Corp 14

Handy & Harman 77
Horsburgh & Scott Co 16
Humphrey Products Div., General Gas Light Co. 82

International Nickel Co., Inc. 64
Invo Spline, Inc. 82

Kaupp & Sons, C. B 4
Kaydon Engineering Corp 7

Lamb Electric Co., Div., Ametek, Inc 63
Linde Co., Div. of Union Carbide Corp. 75
Link-Belt Co. 5
Lucas-Milhaupt Engineering Co 62

McLouth Steel Corp 17
Marsh Instrument Co., Div. of Colorado Oil & Gas Corp. 84
Masland Duraleather Co., The, Industrial Products Div. 67
Midwest Steel Div., National Steel Corp 8
Minnesota Mining & Mfg. Co., Adhesives, Coatings, Sealers Div 70
Molded Fiber Glass Co 6

National Seal Div., Federal-Mogul-Bower Bearings, Inc. ..... 3rd Cover
New Departure Div., General Motors Corp 10
Nicholson & Co., W. H 79

Recordak Co., Subs., Eastman Kodak Co 1
Robbins & Myers, Inc 65
Russell, Burdsall & Ward Bolt & Nut Co 76

SKF Industries, Inc 15
Schrader's Sons, A., Div., Scovill Mfg. Co., Inc 9
Set Screw & Mfg. Co. 82

Tomkins-Johnson Co. 69
Torrington Co., Bearings Div. 68

U. S. Steel Corp 57-61

Valcor Engineering Corp 78
Vlier Engineering Corp., Subs., Barry-Wright Corp. 18

Weirton Steel Co., Div., National Steel Corp 8
Western Rubber Co 62
Wiegand Co., Edwin L. 78
Worthington Corp. ..... 2nd Cover

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CLASSIFIED ADVERTISING
F. J. Eberle, Business Mgr.
Employment Opportunities 86

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3	26	49	72	95	118	141	164	211	234	303	326	349
4	27	50	73	96	119	142	165	212	235	304	327	350
5	28	51	74	97	120	143	166	213	236	305	328	351
6	29	52	75	98	121	144	167	214	237	306	329	352
7	30	53	76	99	122	145	168	215	238	307	330	353
8	31	54	77	100	123	146	169	216	239	308	331	354
9	32	55	78	101	124	147	170	217	240	309	332	355
10	33	56	79	102	125	148	171	218	241	310	333	356
11	34	57	80	103	126	149	172	219	242	311	334	357
12	35	58	81	104	127	150	173	220	243	312	335	358
13	36	59	82	105	128	151	174	221	244	313	336	359
14	37	60	83	106	129	152	175	222	245	314	337	360
15	38	61	84	107	130	153	200	223	246	315	338	361
16	39	62	85	108	131	154	201	224	247	316	339	362
17	40	63	86	109	132	155	202	225	248	317	340	363
18	41	64	87	110	133	156	203	226	249	318	341	364
19	42	65	88	111	134	157	204	227	250	319	342	365
20	43	66	89	112	135	158	205	228	251	320	343	366
21	44	67	90	113	136	159	206	229	252	321	344	367
22	45	68	91	114	137	160	207	230	253	322	345	368
23	46	69	92	115	138	161	208	231	300	323	346	369

370	380	390	
371	381	391	
372	382	392	
373	383	393	
374	384	394	
375	385	395	
376	386	396	
377	387	397	
378	388	398	
379	389	399	

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3	26	49	72	95	118	141	164	211	234	303	326	349
4	27	50	73	96	119	142	165	212	235	304	327	350
5	28	51	74	97	120	143	166	213	236	305	328	351
6	29	52	75	98	121	144	167	214	237	306	329	352
7	30	53	76	99	122	145	168	215	238	307	330	353
8	31	54	77	100	123	146	169	216	239	308	331	354
9	32	55	78	101	124	147	170	217	240	309	332	355
10	33	56	79	102	125	148	171	218	241	310	333	356
11	34	57	80	103	126	149	172	219	242	311	334	357
12	35	58	81	104	127	150	173	220	243	312	335	358
13	36	59	82	105	128	151	174	221	244	313	336	359
14	37	60	83	106	129	152	175	222	245	314	337	360
15	38	61	84	107	130	153	200	223	246	315	338	361
16	39	62	85	108	131	154	201	224	247	316	339	362
17	40	63	86	109	132	155	202	225	248	317	340	363
18	41	64	87	110	133	156	203	226	249	318	341	364
19	42	65	88	111	134	157	204	227	250	319	342	365
20	43	66	89	112	135	158	205	228	251	320	343	366
21	44	67	90	113	136	159	206	229	252	321	344	367
22	45	68	91	114	137	160	207	230	253	322	345	368
23	46	69	92	115	138	161	208	231	300	323	346	369

370	380	390	
371	381	391	
372	382	392	
373	383	393	
374	384	394	
375	385	395	
376	386	396	
377	387	397	
378	388	398	
379	389	399	

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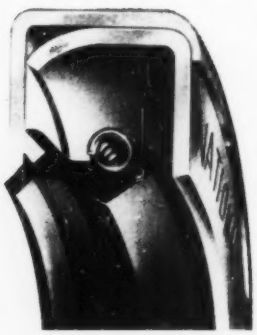

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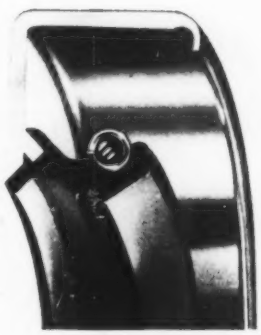

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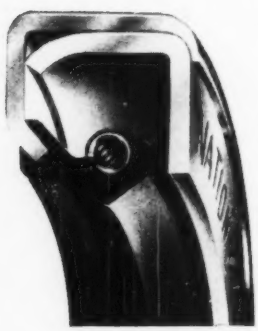

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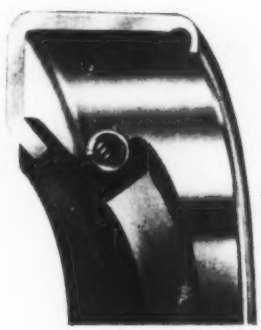

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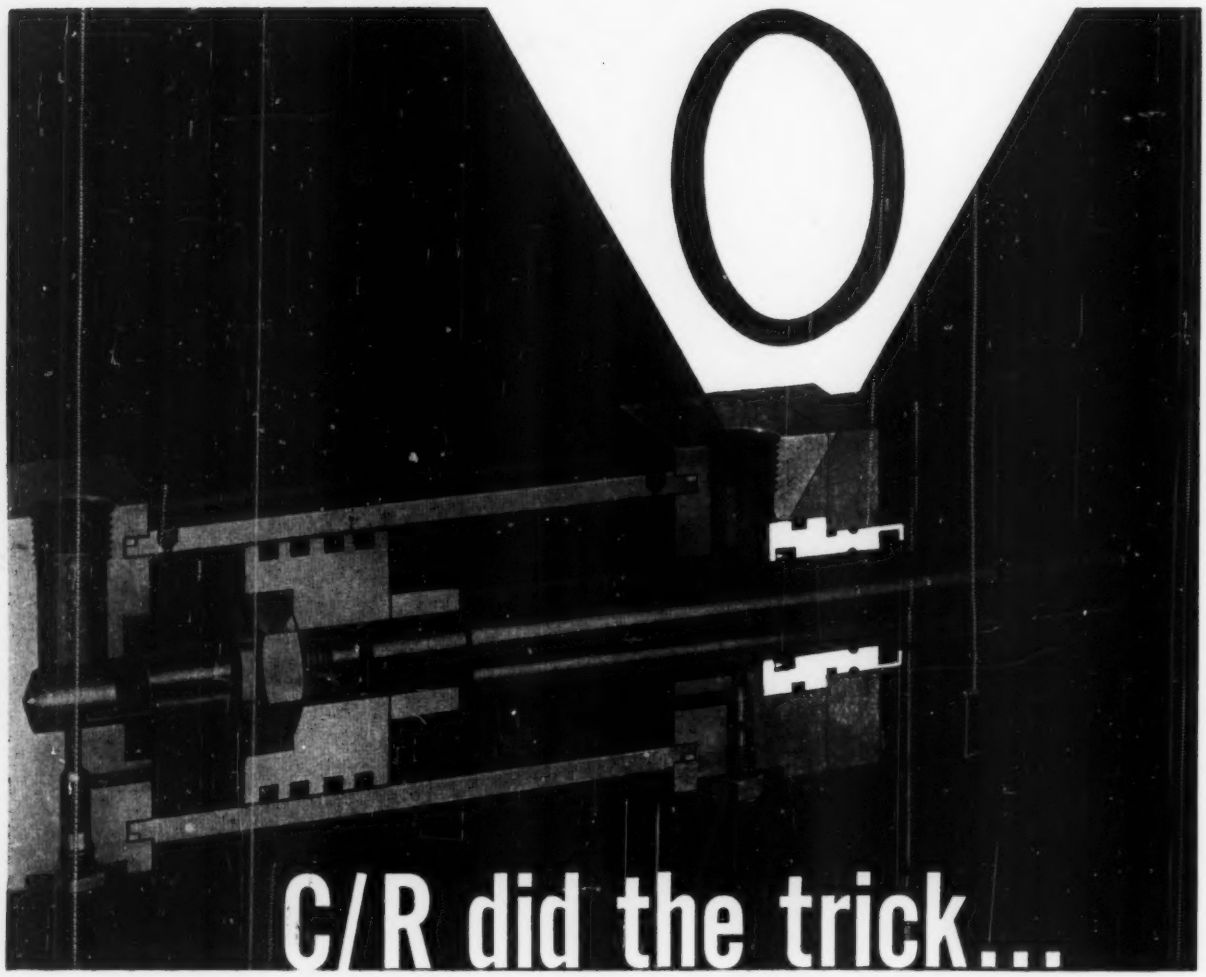

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